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The first Electron Beam of the Fermi@Elettra Free Electron Laser

“A centre of excellence that does great credit to Italy, and especially to the Italian researchers who can fully express their talents here”.

This was the statement by Mariastella Gelmini, Minister of Education, Universities, and Research, on November 30 last, after her visit to the Sincrotrone Trieste Laboratory. The visit took place on the occasion of the official switching-on of FERMI@Elettra’s electron beam produced by the photocathode source and accelerated through the first sections of the 1.5 GeV Linac. FERMI@Elettra is the VUV to soft-Xray free-electron laser entering now the commissioning phase of the electron parts, while the construction of the photon production parts and of the experimental users hall are entering the final phase. FERMI will add a second light source to the synchrotron already operating in the Elettra Laboratory, and will have two FEL sources producing light flashes in the 10-100 femtosecond range with brilliance several billion times higher and fundamental wavelengths between 40 and 5 nanometers. The two sources are complementary and allow both the static and dynamic measure of electron and atomic phenomena. The synchrotron source has been recently upgraded with a new booster injector allowing “top-up” operation and higher stability and photon yields, reaching the specifications of the best new synchrotrons coming on line recently.

The Laboratory operates based on a full “open access” policy, open to the best proposals responding to the two yearly calls, which come from over 30 Countries in the world and are selected solely on the basis of peer review.

The developments and operation of Elettra are monitored and evaluated by international advisory Committees and this is a continuous stimulus towards improvement. This was acknowledged and praised by the Minister which was welcomed to Elettra, by Carlo Rizzuto, President of Sincrotrone Trieste and of the European Strategic Forum for Research Infrastructures (ESFRI), by Alfonso Franciosi, Scientific Director and CEO and Giovanni Comelli, VicePresident, as well as and by various regional and national political authorities.

The inauguration ceremony took place after Minister Gelmini visited the synchrotron experimental hall, and in particular the Collaborating Group’s beamlines by Austria and the Czech Republic as well as the medical high definition radiography beamline SYRMEP. The first generation and acceleration of the electron bunches of FERMI@Elettra was followed live from the screens of the new control room and took place in the newly built FERMI electron generation building and lengthened Linac tunnel. The first results on the bunch charge and definition of the beam are very encouraging and well within the specifications. All other remaining buildings, the undulator hall, service hall, experimental hall, and the mechanical and electrical plant buildings, are under construction. Full functionality of electrical and mechanical plants is planned for May 2010 while the installation of all transfer lines, undulators of FEL I, along with the first beamlines and experimental
stations, is expected to be completed and enter commissioning by fall of the same year. The first user operations of FEL I scheduled to begin in January of 2011, while FELII will be completed during 2011.

“It is with great satisfaction - commented Carlo Rizzuto – that we welcome Minister Gelmini today, and receive her important acknowledgement of Elettra’s quality and international vocation which is now strengthened within the framework of the EUROFEL consortium – one of the ESFRI strategic projects included in the European Roadmap”. The construction of FERMI@Elettra requires and develops unique skills and infrastructure, both in-house and through collaborative efforts with important European and U.S. institutes and agencies, with significant outcomes for the scientific and industrial network. These skills and efforts will be used, after the completion of FERMI, in the construction of other Research infrastructures now being planned in Europe. It was also underlined that the technical and scientific merits of Laboratorio Elettra have already earned it the rank of associate of the International Atomic Energy Agency and of the Central European Initiative. Rizzuto stressed also the importance of research infrastructures, which are useful and necessary in all scientific fields as strategic hubs whose scientific, technical, and managerial quality attract the best researchers from throughout the world, and provide services to develop cutting edge research, techniques, technologies, and scientific education. “Such infrastructures, when they are put in the service of researchers selected on the basis of international competitions, play a leading role in the construction of the European Research Area, as a basis for developing competitiveness and innovation”.

The Elettra and Fermi@Elettra Free Electron Laser facilities.
Concerted proton tunnelling in ordinary ice

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ABSTRACT
We present incoherent neutron scattering measurements which reveal the presence of non-harmonic motions of protons in ordinary ice Ih down to 5K. A quasi-elastic scattering contribution, corresponding to a fast (~3 ps) and localized motion, has been observed. The corresponding dynamics is related to the hydrogen disorder since it is absent in the hydrogen-ordered phase, ice VIII. A main jump distance of 0.75 Angstrom is identified, i.e. close to the distance between the two possible proton sites along the oxygen-oxygen bond. The observed dynamics is non-Arhenius, has a large time rate 2.7 x10^{11} s^{-1}, and affects only a small amount of the total number of hydrogen atoms in the crystal. A partial (20 %) deuteration of the sample hinders the observed dynamics. These observations strongly suggest the existence of concerted tunnelling of hydrogen atoms within the hexagonal rings of ice Ih, as predicted by Pauling [L. Pauling, J. Am. Chem Soc. 57, 2680, (1935)].

Most of the complex behaviour shown by water and other hydrogen bonded systems, including biological solutions, is connected to the presence of the hydrogen bond networks. Almost all hydrogen bond networks are also complicated by the presence of an intrinsic disorder of the hydrogen atoms, which is characteristic of these systems [ziman]. The particular nature of the hydrogen bond networks is the origin of many complex features, e.g. the propagation of soliton-like defects [xu] or the zero temperature entropy of ice [ziman, hobbs]. The ordinary form of the solid phase of water, ice Ih, is one of the most studied hydrogen bond system showing hydrogen disorder. Ice Ih can be considered as the prototype of systems showing the so called ice disorder [ziman]. The average static distribution of hydrogen atoms has been studied in great detail employing neutron diffraction [leman]. However the behaviour of a single proton cannot be determined in a diffraction experiment, as the Bragg diffraction results from the long range structure of the system, averaged on a long time scale.

On the other hand the intrinsic disorder of the hydrogen bond networks in ice gives rise to a diffuse neutron scattering cross section which has been studied in detail in heavy ice, thus concluding that the Bernal-Fowler rules are essentially correct [diffuse]. The ice Ih structure (Figure 1) forms a perfect tetrahedral network of hydrogen bonds. Its principal units are buckled hexagons with the oxygen at corners and one single hydrogen between. There are six different orientations possible for a water molecule in its tetrahedral bonding environment, each corresponding to a different arrangement of protons in its four H-bonds. In ice Ih all the possible orientations of the water molecule at each lattice site are equally realized, thus giving rise to a fully proton-disordered phase [leman]. That implies that there exist two hydrogen sites per oxygen-oxygen bond, both being statistically equally occupied. It is important to observe that, assuming the random distribution of the protons on the oxygen-oxygen bonds, there exist special
rings where the hydrogen is ordered within a hexagonal loop, i.e. where there is an ordered sequence of covalent and hydrogen bonds. We will call these in the following ordered loops. Such loops can appear in both boat-like (Figure 2a) and chair-like rings (Figure 2b) and have a statistical occurrence of 1/32 in a defect-free network. In 1935 L. Pauling, employed a simple counting argument to explain the zero temperature entropy of ordinary ice, and thereby considered also the possibility of concerted jumps of hydrogen atoms in ordered loops [paul].

Beyond the Pauling simple approach the ordered loops can play a special role in proton dynamics as all the six protons can move, in a concerted way, from one allowed position to the other along each bond, without change of the total energy and entropy of the crystal. It is also important to observe that the jumps of the protons are confined to the ordered hydrogen loops and the protons cannot jump from one loop to the other without producing Bjerrum and ionic defects, which are characterized by a high activation barrier [hobbs] and, as a consequence, to by a very low occurrence at low temperatures.
Therefore the jump mechanism in the ordered loops does not contribute to the proton transport within the crystal, i.e. the transport is related only to existence of defects [podes]. The phenomenon of coordinated jump of

Figure 1. Pressure-Temperature phase diagram of ice. The experimental path followed for the production of the ice VIII sample is indicated by dotted arrows. The T-ranges at ambient pressure where the QENS spectra of the three phases ice VIII (blue), ice Ic (red), and ice Ih (green) have been collected are indicated by continuous arrows. The average structure of the 3 phases investigated is also represented.
protons has been observed quite recently [jump\textsubscript{1},jump\textsubscript{2}] in some molecular solids containing cyclic loops of H bonds, but so far not in ice Ih. To study the time-resolved proton distribution in ice Ih, we performed a set of measurements devoted to the determination of its incoherent quasi-elastic scattering intensity as a function of both momentum transfer and temperature. Although no simple experiment can be performed which is sensible to the space-time correlations of more than two particles, we will show that the present quasi-elastic neutron scattering measurements strongly support the existence of a concerted motions of protons in ice Ih cyclic rings.

The quasi-elastic measurements were performed on the time-of-flight spectrometer IRIS at the UK spallation Source ISIS (Chilton, Didcot) with an energy resolution of 15 \(\mu\text{eV}\), and in an energy range between -200 and 1200 \(\mu\text{eV}\). In order to be sensible to small deviations (~10\textsuperscript{-5} in elastic peak intensity) from the resolution broadened elastic peak we collected 24-hours scans for each temperature at each sample (see in the following). We measured with a comparable statistic the empty container, the empty cryostat, the sample-shape absorber, and the standard vanadium inserted into the sample cell [mult]. We designed a hollow cylinder sample cell, which allowed minimizing the sample self-shielding and multiple scattering. These two quantities have been estimated as a function of transferred energy, by an iterative Monte Carlo simulation [mult], and subtracted from the total scattering intensity.

A thin wall aluminium cell was used in order to minimize the scattering due to the cell itself. In order to probe the possibility of dynamics linked to proton-disorder we compared the incoherent quasi elastic scattering spectra of ice Ih to one of the ones of the fully ordered phase of ice, ice VIII, and of a different proton disordered phase, ice Ic. In Ice Ic the oxygen atoms form a diamond lattice and hydrogen atoms are fully disordered with hydrogen-bond lengths identical with those in ice Ih (see Figure 1). However, the appearance of broad reflections in neutron diffraction experiments with intensities not in agreement with a simple cubic structure, indicate the existence of faults in the stacking sequence [Ic].

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Figure 2. Snapshots of two possible proton distributions in “boat-like” (a) and “chair-like” (b) ordered rings.
These stacking faults most likely reduce the number of ordered hexagonal loops. Ice VIII is formed from Ice VII by lowering its temperature. It is fully proton ordered as Ice VII undergoes a proton disorder-order transition to Ice VIII when cooled at about 278K. Its structure can be visualized as two ice Ic structures completely intertwined with one another (see Figure 1). The proton-ordered structure hinders the concerted jump mechanism aforementioned. A sample of 500 mm$^3$ of ice VIII was prepared following a procedure described in Ref. [klotz], produced in a Paris-Edinburgh press at 2 GPa and recovered at liquid nitrogen temperature.

We measured first the ice VIII sample in the temperature range between 5 K and 120 K, where ice VIII is stable. Subsequently the sample was warmed up to T>145 K, where it transformed to ice Ic. The ice Ic sample was measured from 160 K down to 5 K. Finally the ice Ic sample was warmed again up to T>200 K where it converted to ordinary hexagonal ice, and measured at several temperature between 5 K and 260K. We want to stress that the three samples were obtained by phase transformation under temperature annealing of the same sample. The complete transformation into a specific phase and the absence of contamination by different phases was checked by the diffraction pattern collected on the diffraction bank of the instrument.

The measured incoherent quasi-elastic cross section in the three ice phases at 5 K is compared in Figure 3, where the instrument resolution is also reported. The presence of a quasi-elastic contribution in ice Ih beyond the experimental resolution is evident. The quasi-elastic contribution is absent in the H-ordered phase ice VIII, whose elastic peak width cannot be
distinguished from the instrumental resolution, while it is present in ice \textit{Ic}, although with a reduced intensity. This comparison indicates that the quasi-elastic contribution has its origin in the disorder-related motion of protons which are prevented in the H-ordered ice. The production procedure of ice \textit{Ih} by phase transformation in the path ice \textit{VIII-ice Ic-ice Ih} was crucial in order to rule out that the small quasi-elastic signal observed in the proton-disordered phases did not derive from spurious effects, such as for example multi-phonons contributions or multiple scattering diffuse scattering, or surface effects.

![Figure 4](image.png)

\textbf{Figure 4.} Wave-vector dependence of the Full Width at Half Maximum (FWHM) of the quasi-elastic contribution in hexagonal ice (open dots) and cubic ice (triangles).

Taking into account that the phonon vibration contribution is flat in the quasi-elastic energy window we considered, here -0.2 meV to +0.2 meV, we modelled the experimental spectra of ice \textit{Ih} by the sum of a delta function, which describes the elastic contribution, and of a Lorentzian, which models the additional quasi-elastic contribution. Both were convoluted with the instrument energy resolution \( R(Q,\omega) \). Hence, the functional form for the spectra used to fit the experimental data is:

\[
S(Q,\omega) \otimes R(Q,\omega) = e^{-A(T)Q^2} \left[ \left( 1 - C(Q,T) \right) \delta(\omega) + \frac{C(Q,T)}{\pi} \frac{\tau_c}{1 + \omega^2 \tau_c^2} \right] \otimes R(Q,\omega) \quad (1)
\]

where \( e^{-A(T)Q^2} \) is the (quasi-harmonic) Debye-Waller factor, \( C(Q,T) \) is the intensity of the quasi-elastic process, and \( \tau_c \) is the time scale associated with the dynamical process. Applying this simple fitting model to the measured spectra
we could derive the wave-vector and temperature evolution of the intensity and of the time rate. As showed in Figure 4, the quasi-elastic component exhibits a Q-independent width of approximately $\sim 350 \mu eV$ in hexagonal ice and of $\sim 460 \mu eV$ in cubic ice, corresponding to a time scale of 3.7 ps and 2.9 ps, respectively. The time scale of the motion is almost constant up to 100 K and after slightly decreases with temperature. Such short time scales are incompatible with a rotational motion of the water molecule around the oxygen, a localized process that would involve times of the order of ns [stro].

Figure 5. Temperature evolution of the energy integrated quasi-elastic fraction $C(Q,T)$. Full lines represent the best fit curves of the double well model described in the text.

Moreover, the non-Arrhenius behaviour of the measured time scale excludes a classical jump or a cage-confined motion of the proton as driving mechanism. The very high time rate ($k_0 = 2.7 \times 10^{11} \text{ s}^{-1}$) implies an activation energy barrier [note] for the process of the order of few meV. This seems to be incompatible with any simple rearrangement of the proton in the bond which would produce an ionic defect, whose energy barrier is much higher. Finally, we want to remark that from the integral of the quasi-elastic contribution we can estimate the fraction of protons involved in the motion, which is of the order of 3% in ice \textit{Ih} and of 2% in ice \textit{Ic}, i.e. compatible with the fraction of H belonging to ordered loops. Also the observation that the quasi-elastic contribution is lower in cubic ice respect to ordinary ice, is compatible with the aforementioned reduced number of hexagonal loops in ice \textit{Ic}.

To get further insights into the distances involved in the proton motion, we analyzed the wavevector decay of the elastic incoherent structure factor (EISF), showed in Figure 5, and here corresponding to $I - C(Q,T)$ times the
Debye-Waller factor, if the elastic intensity is integrated over a broad energy domain. A first interesting result is that the EISF decay cannot be described by a simple Gaussian Debye-Waller factor at each temperature, as it is the case for a harmonic crystal, where the dynamics is purely vibrational. This can be readily interpreted as a complex, non-harmonic behaviour of the protons in ice, which is not easily seen by means of other techniques.

A fit of the EISF with an anharmonic Debye-Waller factor of the form $e^{-[A(T)Q^2+B(T)Q^4]}$ has been tempted. However, the results obtained where unreliable since the coefficient $B(T)$ of the anharmonic $Q^4$ term proved to be temperature independent. Therefore, the usual harmonic form for the Debye-Waller factor deduced by diffraction data [leman] was assumed, and the additional decrease of the elastic intensity with increasing $Q$ was ascribed to the presence of the observed non vibrational motion. Under the assumption of a tunnelling process of the proton between two minimum positions of the potential in the bond, we can rewrite the integrated fraction of quasi-elastic contribution in a powder sample as [doster]:

$$C(Q,T)=2 \ p_1 \ p_2 \ (1-\sin(qd)/(qd))$$

(2)
where $p_1$ and $p_2$ are the equilibrium populations of the two sites separated by a distance $d$. The increase of quasi-elastic intensity as a function of wavevector that we observe in ice $I_h$ on increasing the temperature is well described by this simple model. The experimental data can be fitted very well by using the previous expression for $C(Q,T)$ and the resulting parameters are quite meaningful: the transition probability $p_2$ is non-zero also at the lowest temperature, showing a smooth temperature dependence, while the distance $d$ turns out to be temperature independent and coincides almost with the distance between the two possible proton sites along the oxygen-oxygen bond, i.e. $d = 0.75$ Angstrom. This result strongly supports the identification of the localized dynamics with a proton jump between the two allowed sites in the bond. Moreover, the non-Arrhenius temperature dependence of the population factor, $p_1 p_2$, reported in Figure 6, and the aforementioned T-independence of the tunnelling time up to $100$ K, indicate that the observed motion can be identified with a quantum proton tunnelling process, which is phonon assisted at the higher temperature. As previously discussed, we can exclude that a single proton tunnelling between the two proton sites is at the basis of the observed phenomena. This process is ruled out at the low temperature by the strong constraints imposed by the Bernard-Fowler rules.

The concerted proton tunnelling mechanism in the ordered loops seems to be the simplest mechanism which is compatible with the experimental results. However, it remains to be proved by theory that the energy barrier for such a process is sufficiently low under realistic conditions, to fit with the high time rate found for the observed dynamics. A full quantum path-integral calculation of a lattice containing at least one ordered loop could definitively shed light on this point. However, this is a non-trivial and, due to the high number of atoms to be considered, numerical time-consuming task which is beyond the aim of our experimental study. Further sustain to the attribution of the observed non-harmonic dynamics to a collective proton tunnelling process in the cyclic loops is given by the observation that the quasi-elastic signal is absent in hexagonal ice formed by a 1:4 mixture of deuterium and hydrogen. In such partially deuterated sample a complete breaking of the symmetric cyclic is statistically assured [prl]. This further corroborates the assignation of the observed dynamics to a concerted movement involving several H-atoms in the hexagonal rings.

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[note] $k_0$ is proportional to the square of the tunnelling element of matrix $A$ that characterizes the double well potential between the two configuratons of the system, for further details see [Skinner, Trommsdorff, J.Chem Phys 89, 1988].
Prompt Gamma Activation Analysis of bronze fragments from archaeological artefacts

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ABSTRACT

The Prompt Gamma Activation Analysis facility of the Budapest Research Reactor has been adopted as a non-destructive elemental analytical technique to investigate bronze archaeological artefacts belonging to the Picenum necropolis of the Matelica site, Italy. These objects date back to the 7th century B.C. and they have been discovered during a rescue excavation carried out in the period 1994-2005. 17 fragments selected from the archaeological finds have been analyzed, together with a bronze fragment belonging to the archaeological area of Fabriano, Italy. The major components have been determined of all the analyzed objects, and some trace elements - e.g., Sb, As and Ag - have been identified. The comparison of the compositions of the different samples allowed to achieve information on the possible provenance, being useful, moreover, to set up a classification according to the chemical composition.

INTRODUCTION

The Italian town of Matelica is placed in the Marche region and precisely in the Esino River valley at a distance of about seventy kilometres from the Adriatic Sea. The Roman historian Plinio il Vecchio (1st century A.D.), in his main work, cited this town with the name of Matilica and put it in the Regio VI (corresponding approximately to the current Umbria region) and not in the Regio V Picenum (corresponding approximately to the territory of the current Marche region) [1]. Matilica was a Municipium at least from the half of the 1st century A.D. and it reached the greatest magnificence between the 1st and the 2nd century A.D. The period of its decline, as per various other demic diffusions into that zone, reached its peak in concomitance with the passing of foreign barbaric troops from the 5th century A.D. onwards.

Matelica is a commercial place of exchanges and crossroads of important trans-appennine communication lines from at least 3,000 years. In the last three lustra, it saw a proliferation of occasional and also planned archaeological excavations presaging of sensational findings, which oblige the experts to rewrite the history of this boundary zone between the area of Umbrian and that of Picenan influence. Figure 1 refers to the recent excavation in the Matelica archaeological site. The Piceni (or Picentes) belong to the pre-roman Culture that gravitated in this central part of Italy essentially from the 10th to the 3rd century B.C., in practice the so called “Iron Age”. The remains emerged in the Matelica area emphasize extensive necropoles already from the 9th-8th century B.C., while the remains of the built-up areas date back to the period 7th-4th century B.C. The archaeological documentation is essential to understand the Picenan civilization as well as a lot of other Italic cultural facies before the Romanization: in fact, the ancient proofs coming from the Greek and Roman classic sources are not many and the information achieved from the Picenes in their own language (usually, wrecks of short funereal inscriptions or religious dedications diversely interpreted) are not yet enough studied. Funereal
Matelica Picenum necropolis, Italy

equipments are, obviously, the major part or the emerged remains, which provide us the most consisting quantity of scientific information. Also thanks to the findings of Matelica, the recovered fragments of Picenan inhabited structures are no more so rare; for their nature of typical proto-urban architectures, they present intrinsic motives of structural fragility (being mainly huts edified by using perishable elements, e.g. wooden and stramineous materials, pile pierces, raceways, fireplaces and little dry walls). The very favourable synergy developed between the territorial Local Board (Municipality of Matelica) and the Public Authority in charge for the protection and the exploitation of the Cultural Heritage (Superintendence for the Archaeological Heritage of Marche Region) has allowed, in the last years, to broaden remarkably the knowledge of this subject.

It is possible, in this way, to express in our time new hypotheses and, therefore, to advance different socio-economical and cultural scenarios: they throw a new light on a reality that anciently was very complex and vital and of which, at the present state of the art, we maybe do not succeed to understand still enough the complicated events [2–10]. Chemical analysis of archaeological artefacts (metal objects, ceramics, polished stone tools, sculptures, etc.) has become, recently, an important tool for source identification, provenance analysis based on the determination of major- and trace elements.
The most usual analytical methods - e.g. X-Ray Fluorescence Spectroscopy (XRF), Instrumental Neutron Activation Analysis (INAA) and Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) - require partial or total destruction of the samples, which often is not allowed in case of valuable whole or fragmental artefacts; another method has been recently developed - the time-domain terahertz (Td-THz) imaging -, which consents in-situ mapping of the internal layer-structure of the artefact [11]. Neutron investigations have recently become an increasingly significant probe for materials across a wide range of disciplines and can reveal significant properties about materials. Neutrons are becoming ever more useful in the non-destructive characterisation of materials and components of archaeological and industrial interests. For instance, the industrial applications of neutron techniques are being developed in various new sectors [12-13]. Prompt Gamma Activation Analysis (PGAA) is based on the detection of characteristic prompt gamma photons that originate in \((n,\gamma)\) nuclear reactions. Every atomic nuclei, apart from \(^4\)He, may undergo a \((n,\gamma)\) reaction with diverse probabilities and the energies of the emitted gamma photons are characteristic for every given isotope. The intensities of the gamma peaks are proportional to the amount of a given isotope and this phenomenon consents to use a quantitative elemental (isotopic) analysis method known as PGAA or PGNAA (Prompt Gamma Neutron Activation Analysis) [12, 14 and 15]. The principles of the method have been well known for decades. Since neutrons are able to go through deeper - as well as the surface - layers of the material, PGAA provides information on the sample as a whole without differentiating between “bulk” and “surface” composition of the investigated

Figure 2. Original *situla* and its fragments analyzed by PGAA, with reference to the sample No. 1.

Figure 3. Original *cista* and its fragments analyzed by PGAA, with reference to the sample No. 6.
object: consequently, complementary analytical investigations are suggested - e.g., proton induced X-ray emission (PIXE) -, whenever an important effect of weathering is presumed on the surface. An important feature of PGAA is that it is a multi-element method: both the major components and a variety of trace elements can be detected in different types of objects, although with different sensitivities. The elements detectable with the highest sensitivities are B, Cd, Sm and Gd (with a detection limit ~0.1 μg/g). C, N, O, F, Sn, Pb and Bi (with detection limits above 1000 μg/g) are the elements most difficult to identify. Sensitivities for every chemical element have been determined, using internal standardization or comparator measurements at the BRR. The detection limits depend on the composition of the investigated sample and can be enhanced by increase the acquisition time.

**EXPERIMENTAL**

Since bronzes are considered significant to confirm eventually the hypothesis of a local manufacturing place of the studied artefacts, the Superintendence for the Archaeological Heritage of Marche Region has appointed Rogante Engineering Office to investigate by PGAA 18 bronze fragments, 17 coming from the Matelica area and one, as a comparison, coming from the Fabriano area. This last fragment belongs, in particular, to a biconical discovered by I. Dall’Osso in 1915 [6] in the tomb No. 3 of Santa Maria in Campo site and represents the most relevant artefact either as a finding of that area, or for the purpose of the present study, because its provenance from a local metallurgical area is well known.

The 17 bronze fragments of the Matelica site form part of the following artefacts discovered in six different tombs: *situlae, patera, cista*, helmets, washbowls, lance prong coil, ring and *tripode* [16, 17]. Table 1 describes the major typological information and locations where the archaeological
bronzes have been collected. Figures 2 to 8 show the original artefacts and their fragments analyzed by PGAA, with reference to samples No. 1, 6, 7, 8, 9, 10 and 14 respectively, while Figure 9 shows the sample No. 11. The investigation has been complementary to atomic absorption, atomic emission and neutron diffraction. The measurements were performed at the PGAA facility at the 10 MW BRR (see Figure 10). This instrumentation has been developed since 1996. A guided thermal neutron beam of $2.5 \times 10^6$ cm$^2$s$^{-1}$ flux, supplied by the BRR, was used until 2000 for analysis [18]. The thermal equivalent flux of the cold beam, at the time of these measurements, was $5 \times 10^7$ cm$^2$s$^{-1}$; successively, between January and October 2007, the first two upgrades of the neutron guides were performed and a thermal equivalent flux of $7 \times 10^7$ cm$^2$s$^{-1}$ was achieved. A final third upgrade, then, allowed the use of an intensity of $1.2 \times 10^8$ cm$^2$s$^{-1}$.

The neutrons are guided by Ni-coated guide tubes towards the sample position, which is approximately 35 m away from the reactor core. The beam's usual cross section is $2 \times 2$ cm$^2$ and it can be reduced to $1 \times 1$ cm$^2$ or even to a smaller area. The prompt-gamma photons are detected by a complex detector system, which contains an n-type high-purity germanium (HPGe) main detector with a Bismuth Germanate (BGO) scintillator detector annulus to perform Compton-suppression measurements. The Compton-suppressed HPGe detector has been precisely calibrated [19] and the gamma-ray spectra have been evaluated using the Hypermet-PC program [20, 21].

The quantitative analysis was based on the $k_0$ principle [22], while the composition has been determined using the methods described in ref [23] and the uncertainties of the concentration values according to [24]. The spectroscopic data libraries have been developed at the Institute of Isotopes of the BRR [25].

The investigation strategy, in general, has consisted in providing information on the considered artefacts, including a technological description and a comparative analysis, with the aim to better identify their provenance and eventual relationships with known features of other production. The bronze fragments have been basically placed into the normal sample
position and irradiated in the cold neutron beam. The neutron beam cross-section was $2 \times 2$ or $1 \times 1$ cm$^2$, depending on the sample dimensional characteristics. Figure 11 shows the sample No. 16 fastened with Teflon strings onto the aluminium frame and being placed into the PGAA measurement chamber.

A number of bronze fragments, due to their small size, have been irradiated in vacuum to decrease the measured spectra background. A 5000 to 50000 seconds time for data acquisition has been chosen, depending on the sample size, to achieve reasonable statistics for spectrum evaluation.

RESULT

PGAA consented to determine the major elements of Cu and Sn, while the amount of Pb was under the detection limit in all the investigated samples. Additional minor components of Fe, Co, Zn, As, Ag and Sb have been detected in some of the objects. The presence of H, Si, and Cl can be ascribed to contamination from the environment. Table 2 reports the detailed PGAA results, including the concentrations under the given detection limits.

The approximate detection limits found for the investigated bronze fragments were (in wt%): Zn: 0.5, Sn: 2, Pb: 2, H: 0.005, B: 0.00003, Al: 1.5, Si: 1.6, P: 3.1, S: 0.3, Cl: 0.05, K: 0.74, Ca: 1.8, Ti: 0.09, Cr: 0.1, Mn: 0.22,
Fe: 0.48, Co: 0.014, Ni: 0.078, As: 0.28, Ag: 0.049, Cd: 0.0009, Sb: 0.55, Au: 0.037, Hg: 0.006, supposing a 10000 s irradiation of a 0.1 cm thick sample with a 2x2 cm² beam. Figure 12 shows the PGAA spectrum resulting from the investigation of the sample No. 3. The Sn/Cu mass ratios have been determined, furthermore, with the aim to compare the alloying composition of the investigated bronze artefacts (see Figure 13). This figure shows very evidently that no significant differences, except for the sample No. 6, can be individuated by comparing the bronze objects of the Matelica archaeological site - of which the metallurgical area of provenance was not sure - with the biconical from Fabriano site (sample No. 14). This contributes to confirm the compositional uniformity of the bronze objects between the two considered areas. The sole sample No. 6 (cista found in the Tomb 172 of “Crocifisso” site, Matelica), on the other hand, shows a significant difference in Sn/Cu ratios, revealing that it is almost certainly dissimilar from the other archaeological artefacts. A Principal Component Analysis (PCA) has been performed, finally, by means of “XLSTAT” program software (Addinsoft Inc., USA) [26]. PCA is a widespread multivariate numerical method which operates with linear combinations of the original composition data. This method is extensively adopted to carry out comparative studies of archaeological artefacts; moreover, in particular, it is able to reveal various important similarities or differences between the analysed objects taking into account
account their composition [27]. The chart in Figure 14 shows the results obtained from this method, which has proved to be helpful to progress the comparison between the bronze objects of the Matelica archaeological site with that from Fabriano.

These results confirm the consideration above expressed and concerning the samples No. 6 and No. 14. In this chart, also the sample No. 7 (helmet found in the tomb of Villa Clara site, Matelica) seems to be dissimilar from the others: additional investigations on the manufacturing places of the objects, thus, have been recommended. The present work, concerning five of the investigated artefacts, has been included in the database of the Ancient Charm Project [28].

**CONCLUSIONS**

The application of PGAA has been introduced, in the perspective of future studies at 360°, to facilitate the traditional archaeological research to find answers - also very refined - to the historical-archaeological questions that the traditional sources do not succeed by now to get ahead into focus.

This concept follows the practice of the historical science of archaeology, which always uses the support of other disciplines to elaborate and to decipher correctly the dissimilar data normally collected in a stratigraphic excavation. A comparison has been carried out of Aenean objects from

![Figure 12. PGAA spectrum resulting from the investigation of the sample No. 3 (patera wall fragment belonging to a tomb found in Passo Gabella site, Matelica, Italy).](image-url)
Matelica and Fabriano sites, dating back to the 7th century B.C. Most of the major components and some interesting trace elements of the bulk material have been determined, together with Sn/Cu mass ratios and a PCA analysis, providing useful information for the study of the provenance.

### Table 1. Archaeological description of the investigated objects.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Sample name</th>
<th>Archaeological site</th>
<th>Typological information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MAT PG 1 AC</td>
<td>Tomb in Passo Gabella site, Matelica</td>
<td>situla (wall inferior edge fragments)</td>
</tr>
<tr>
<td>2</td>
<td>MAT PG 2 AC</td>
<td>“</td>
<td>situla (upper wall fragment)</td>
</tr>
<tr>
<td>3</td>
<td>MAT PG 10 AC</td>
<td>“</td>
<td>patera (wall fragments) rep. 25</td>
</tr>
<tr>
<td>4</td>
<td>MAT PG 15 AC</td>
<td>“</td>
<td>little situla (wall fragments) rep. 18</td>
</tr>
<tr>
<td>5</td>
<td>MAT PG 18 AC</td>
<td>“</td>
<td>cista handle, rep. 14 (powder, m = 0.1198g)</td>
</tr>
<tr>
<td>6</td>
<td>MAT CR 28 AC</td>
<td>Tomb 172 in Crocifisso site, Matelica</td>
<td>cista (wall fragments)</td>
</tr>
<tr>
<td>7</td>
<td>MAT VC 30 AC</td>
<td>Tomb in Villa Clara site, Matelica</td>
<td>helmet (central element fragment) inv. 63899</td>
</tr>
<tr>
<td>8</td>
<td>MAT VC 31 AC</td>
<td>“</td>
<td>washbowl (wall fragment) inv. 63900</td>
</tr>
<tr>
<td>9</td>
<td>MAT VC 32 AC</td>
<td>“</td>
<td>lance prong coil (fragment)</td>
</tr>
<tr>
<td>10</td>
<td>MAT VC 34 AC</td>
<td>“</td>
<td>ring (fragment)</td>
</tr>
<tr>
<td>11</td>
<td>MAT CR 44 AC</td>
<td>Tomb in Crocifisso new site, Matelica</td>
<td>situla (wall fragment)</td>
</tr>
<tr>
<td>12</td>
<td>MAT CI 48 AC</td>
<td>Tomb 39 in Cimitero site, Matelica</td>
<td>helmet (fragment)</td>
</tr>
<tr>
<td>13</td>
<td>MAT CI 52 AC</td>
<td>“</td>
<td>tripode (wall fragments)</td>
</tr>
<tr>
<td>14</td>
<td>FAB SMC 64 AC</td>
<td>Tomb 3 in Santa Maria in Campo site, Fabriano</td>
<td>biconical (wall fragment)</td>
</tr>
<tr>
<td>15</td>
<td>MAT CR 80 AC</td>
<td>Tomb 182 in Crocifisso site, Matelica</td>
<td>helmet (cap fragment) rep. 88</td>
</tr>
<tr>
<td>16</td>
<td>MAT CR 81 AC</td>
<td>“</td>
<td>washbowl (wall fragment) rep. 39</td>
</tr>
<tr>
<td>17</td>
<td>MAT CR 82 AC</td>
<td>“</td>
<td>situla (wall fragment) rep. 40</td>
</tr>
<tr>
<td>18</td>
<td>MAT CR 83 AC</td>
<td>“</td>
<td>cista (wall fragments) rep. 41</td>
</tr>
</tbody>
</table>
The absence of diversity, i.e. the compositional uniformity revealed between the artefacts discovered in the Matelica and Fabriano sites, in particular, has provided the archaeological community with a further argument to consider Matelica area as a possible manufacturing metallurgical centre independent

<table>
<thead>
<tr>
<th>No.</th>
<th>Inventory No.</th>
<th>H</th>
<th>Si</th>
<th>Cl</th>
<th>Fe</th>
<th>Co</th>
<th>Cu</th>
<th>Zn</th>
<th>As</th>
<th>Ag</th>
<th>Sn</th>
<th>Sb</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MAT PG 1 AC</td>
<td>&lt;0.03</td>
<td>&lt;1</td>
<td>0.02</td>
<td>&lt;0.4</td>
<td>0.016</td>
<td>90.7</td>
<td>0.83</td>
<td>0.21</td>
<td>0.073</td>
<td>7.2</td>
<td>0.93</td>
</tr>
<tr>
<td>2</td>
<td>MAT PG 2 AC</td>
<td>&lt;0.03</td>
<td>&lt;1</td>
<td>0.01</td>
<td>&lt;0.4</td>
<td>0.011</td>
<td>92.3</td>
<td>0.89</td>
<td>0.24</td>
<td>0.119</td>
<td>5.6</td>
<td>0.81</td>
</tr>
<tr>
<td>3</td>
<td>MAT PG 10 AC</td>
<td>0.121</td>
<td>&lt;1</td>
<td>0.04</td>
<td>&lt;0.4</td>
<td>&lt;0.006</td>
<td>92.2</td>
<td>&lt;0.8</td>
<td>0.61</td>
<td>0.128</td>
<td>6.9</td>
<td>&lt;0.4</td>
</tr>
<tr>
<td>4</td>
<td>MAT PG 15 AC</td>
<td>0.065</td>
<td>&lt;1</td>
<td>0.01</td>
<td>&lt;0.4</td>
<td>0.021</td>
<td>88.3</td>
<td>&lt;0.8</td>
<td>&lt;0.2</td>
<td>0.085</td>
<td>11.5</td>
<td>&lt;0.4</td>
</tr>
<tr>
<td>5</td>
<td>MAT PG 18 AC</td>
<td>&lt;0.03</td>
<td>&lt;1</td>
<td>0.02</td>
<td>&lt;0.4</td>
<td>0.059</td>
<td>91.5</td>
<td>&lt;0.8</td>
<td>&lt;0.2</td>
<td>0.122</td>
<td>8.3</td>
<td>&lt;0.4</td>
</tr>
<tr>
<td>6</td>
<td>MAT CR 28 AC</td>
<td>1.265</td>
<td>&lt;1</td>
<td>0.04</td>
<td>0.50</td>
<td>0.010</td>
<td>74.2</td>
<td>&lt;0.8</td>
<td>0.54</td>
<td>0.275</td>
<td>22.3</td>
<td>0.88</td>
</tr>
<tr>
<td>7</td>
<td>MAT VC 30 AC</td>
<td>&lt;0.03</td>
<td>&lt;1</td>
<td>0.02</td>
<td>&lt;0.4</td>
<td>&lt;0.006</td>
<td>84.5</td>
<td>&lt;0.8</td>
<td>3.32</td>
<td>0.064</td>
<td>11.6</td>
<td>&lt;0.4</td>
</tr>
<tr>
<td>8</td>
<td>MAT VC 31 AC</td>
<td>0.076</td>
<td>&lt;1</td>
<td>0.02</td>
<td>&lt;0.4</td>
<td>&lt;0.006</td>
<td>87.2</td>
<td>&lt;0.8</td>
<td>&lt;0.2</td>
<td>0.092</td>
<td>12.7</td>
<td>&lt;0.4</td>
</tr>
<tr>
<td>9</td>
<td>MAT VC 32 AC</td>
<td>0.038</td>
<td>&lt;1</td>
<td>0.03</td>
<td>&lt;0.4</td>
<td>0.024</td>
<td>90.8</td>
<td>&lt;0.8</td>
<td>&lt;0.2</td>
<td>0.052</td>
<td>9.1</td>
<td>&lt;0.4</td>
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<tr>
<td>10</td>
<td>MAT VC 34 AC</td>
<td>0.172</td>
<td>&lt;1</td>
<td>0.01</td>
<td>&lt;0.4</td>
<td>0.006</td>
<td>83.6</td>
<td>&lt;0.8</td>
<td>&lt;0.2</td>
<td>0.059</td>
<td>16.2</td>
<td>&lt;0.4</td>
</tr>
<tr>
<td>11</td>
<td>MAT CR 44 AC</td>
<td>&lt;0.03</td>
<td>&lt;1</td>
<td>0.01</td>
<td>&lt;0.4</td>
<td>&lt;0.006</td>
<td>90.1</td>
<td>&lt;0.8</td>
<td>0.45</td>
<td>0.130</td>
<td>9.3</td>
<td>&lt;0.4</td>
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<tr>
<td>12</td>
<td>MAT CI 48 AC</td>
<td>0.018</td>
<td>&lt;1</td>
<td>0.03</td>
<td>&lt;0.4</td>
<td>0.012</td>
<td>89.5</td>
<td>&lt;0.8</td>
<td>0.23</td>
<td>0.100</td>
<td>9.7</td>
<td>0.40</td>
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<tr>
<td>13</td>
<td>MAT CI 52 AC</td>
<td>0.273</td>
<td>2.8</td>
<td>0.09</td>
<td>&lt;0.4</td>
<td>0.018</td>
<td>82.0</td>
<td>&lt;0.8</td>
<td>&lt;0.2</td>
<td>0.094</td>
<td>13.8</td>
<td>0.41</td>
</tr>
<tr>
<td>14</td>
<td>FAB SMC 64 AC</td>
<td>0.680</td>
<td>1.9</td>
<td>1.01</td>
<td>0.42</td>
<td>0.012</td>
<td>83.4</td>
<td>&lt;0.8</td>
<td>&lt;0.2</td>
<td>0.072</td>
<td>12.9</td>
<td>&lt;0.4</td>
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<tr>
<td>15</td>
<td>MAT CR 80 AC</td>
<td>0.246</td>
<td>1.5</td>
<td>0.02</td>
<td>&lt;0.4</td>
<td>&lt;0.006</td>
<td>85.6</td>
<td>&lt;0.8</td>
<td>&lt;0.2</td>
<td>0.052</td>
<td>11.9</td>
<td>0.67</td>
</tr>
<tr>
<td>16</td>
<td>MAT CR 81 AC</td>
<td>0.280</td>
<td>2.2</td>
<td>0.10</td>
<td>0.45</td>
<td>0.007</td>
<td>86.1</td>
<td>&lt;0.8</td>
<td>0.86</td>
<td>0.160</td>
<td>8.7</td>
<td>1.12</td>
</tr>
<tr>
<td>17</td>
<td>MAT CR 82 AC</td>
<td>1.326</td>
<td>&lt;1</td>
<td>0.05</td>
<td>0.67</td>
<td>0.009</td>
<td>88.6</td>
<td>&lt;0.8</td>
<td>&lt;0.2</td>
<td>0.171</td>
<td>8.4</td>
<td>0.79</td>
</tr>
<tr>
<td>18</td>
<td>MAT CR 83 AC</td>
<td>0.659</td>
<td>3.4</td>
<td>0.09</td>
<td>0.63</td>
<td>0.007</td>
<td>80.6</td>
<td>&lt;0.8</td>
<td>&lt;0.2</td>
<td>0.00</td>
<td>14.1</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Table 2. Results of PGAA measurements.
from that of Etrurian (Tyrrenian) region [29]. A significant difference between some objects has been outlined, on the other hand, which could represent a substantial indication for future discussions from the archaeological point of view. Naturally, the still slight survey at present available of data, deduced with this type of refined and innovative method of objective and non-destructive investigation, presents gaps and inevitable large margin of enhancement.

With this perspective, an increasing number of archaeological objects are being investigated by PGAA, helping also to improve this technique and to make it suitable for industrial applications too - see, e.g., ref. [30].

The progress of research and the formation of a rich and more reliable database will allow to the researchers to gather very interesting and original

Figure 13. Sn/Cu mass ratio of the investigated bronze artefacts.

REFERENCES

9. G. de Marinis et al. (Eds.), “Archeologia nel Maceratese: nuove acquisizioni”, Carima Arte srl, Macerata, Italy, 2005
features (in this case, concerning the metallurgical reality of the past), with potential inestimable scientific effects. “We are now in the forerunner phase, with its responsibilities and honours” [17].

ACKNOWLEDGEMENTS

The Superintendence for the Archaeological Heritage of Marche Region, Italy, is acknowledged for the samples provided. The authors would like to thank EC for its support for access to the BRR facilities, under the 6th Framework Programme through the Key Action: Strengthening the European Research Area, Research Infrastructures. Contract n.: R113-CT-2003-505925.


Figure 14. Principal Component Analysis of Picenum necropolis bronze objects.
The neutron spin echo (NSE) spectrometer was inaugurated by the Forschungszentrum Jülich (Jülich) at the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) on November 4–5, 2009. Participants in the ceremony included Steven Koonin, Under Secretary for Science of the U.S. Department of Energy, Beatrix Vierkorn-Rudolph, head of the Subsection for Large Facilities, Energy and Basic Research of the German Federal Ministry of Education and Research, Sebastian Schmidt, member of the Board of Directors of Jülich, and ORNL director Thom Mason. Construction of the spectrometer was funded by the German Federal Ministry of Education and Research and the Ministry of Innovation, Science, Research and Technology of the federal state of North Rhine-Westphalia and built by Jülich scientists and engineers in strong collaboration with SNS personnel. This effort was initiated by Jülich’s Dieter Richter. As part of the collaboration with SNS, German users will have access to the POWGEN diffractometer and the BASIS backscattering spectrometer at SNS.
Thom Mason, left, ORNL director, discusses Oak Ridge neutron scattering capabilities with Steve Koonin, Department of Energy Under Secretary for Science.

Ferenc Mezei, right, inventor of the NSE technique, discusses the science with a workshop participant.

Examining the NSE spectrometer after its inauguration are, left to right, Michael Ohl (project leader of the NSE, Jülich), Tadeusz C. Kozielewski (lead engineer of the NSE, Jülich), Beatrix Vierkorn-Rudolph (German Federal Ministry of Education and Research), Sebastian Schmidt (chief executive officer, Jülich), Christian Jörgens (Science and Technology department at the German Embassy in Washington), and Jost Liebich (Jülich).
The focus of the NSE spectrometer is soft-matter research, and its capabilities make it useful for other fields of modern condensed matter and materials science. The instrument is especially suited for analyzing slow dynamical processes and will enable increased understanding of molecular motion at nano- and mesoscopic levels. It will be a world-class spectrometer in both resolution and dynamic range, with a goal of six orders of magnitude (from 1 ps to 1 μs) is anticipated using wavelengths between 0.25 <λ/\text{nm} < 2.0 and a unique correctable field integral of 1 Tm.

Following the inauguration ceremony, researchers from Europe, Japan, and the United States attended a two-day workshop on the neutron spin echo technique. The workshop began with Ferenc Mezei’s talk on the history of the spin echo technique. Four sessions then focused on the important challenges to be studied by using this instrument: polymer dynamics, biophysics, complex fluids, and new directions and trends.

In addition, Michael Ohl (Jülich) described the capabilities and performance of the NSE spectrometer. Michael Monkenbusch (Jülich) concluded the workshop with a summary of the presentations and descriptions of the present status of NSE research and its future perspectives. Details of the workshop are available at http://neutrons.ornl.gov/conf/NSE2009/index.shtml.
Trends in Cold Neutron Time-of-Flight spectroscopy, ILL November 25-26

A major upgrade of the IN5 cold neutron time-of-flight (CNTOF) spectrometer at the ILL was achieved about a year ago and the instrument has been in scheduled user operation since then. Over the years the Italian neutron user community has been quite active on IN5. Among the recent work one can cite the investigations carried out by groups based at Milano, Perugia, Messina and Parma for example, with themes of interest in covering a broad range including quasi-elastic scattering and molecular spectroscopy, we can also note the strong involvement in the field of molecular nanomagnets. A workshop dedicated to the successful first year of operation of the renewed IN5 was organized at the ILL recently.

To mark the first year of operation on the renewed IN5, a workshop was held at the ILL on November 26-27, 2009. This multidisciplinary workshop was dedicated to gather the community and the instrument scientists working with CNTOF. The aim announced was to share the recent experience on already operating instruments and those in commissioning phase, as well as to feel the flavor of the new projects foreseen in many neutron research centers.

It was also an occasion to discuss the scientific prospects and opportunities offered by these new instruments, due to increased performance and especially the new feature of PSD detectors that offers a qualitative change of paradigm for the CNTOF. The programme that ran over two days (see detail at http://www.ill.eu/news-events/workshops-events/ticntof/) included

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6, rue J. Horowitz
Grenoble, France
instrumental and sample environment developments, issues concerning data acquisition and treatment as well as an outlook on recent cutting edge experiments carried out and coming up on CNTOF instruments.

The attendance come up to close to 50 persons, and it was a pleasure for the organizers to welcome delegates from essentially all neutron centers with new CNTOF instruments or projects. A highlight and the original motivation of the workshop was the refurbished IN5 that has been in user operation since about a year. The instruments in close to operating and commissioning phase at J-PARC (Amateras), ISIS (LET) were presented. Unfortunately one of the most exciting cases, the CNCS instrument at SNS (Oak Ridge) was not on the agenda of talks due to the heavy workload of the instrument scientists that led to difficulties to attend. Nevertheless a poster from SNS was available for the interest of all. The instrument projects from Korea (Hanaro), Australia (Opal), Germany (HZB and JCNS) and France (LLB) were presented. Some of those are already well advanced, in construction phase, others still examining the optimal configurations based on the needs of the respective scientific communities. A major concern discussed also in many other forums is the difficulty for the detectors due to the limited He3 supply and the associated escalation of cost. Among the themes treated the question of sample environment came up as a critical point in concerning the quality and optimal use of the new powerful instruments. Minimizing the background contribution as well as the time spent on changing parameters, e.g. temperatures or samples is an essential challenge for further development.

The large amount of data acquired with the pixellated position sensitive detectors poses serious question as to the follow-up of the experimental process and the further reduction and analysis of the data. In general a more open and collaborative effort is called for and it seems that this mode of operation is gaining momentum and deserves continuous attention.

As to scientific themes treated it is evident that the new large area position sensitive detectors offer a qualitative step in performance for investigation of single crystal samples. This has been seen in the pioneering work at ISIS and exciting examples from IN5, Amateras and CNCS, were shown at the present workshop. Unfortunately the more traditional quasi-elastic investigations concerning atomic scale diffusion, liquids soft matter and biophysical systems were not present on a scale representative of their share in the instrument use. For those themes the quantitative gain in performance is straightforward as shown by the illustrative example from IN5, quasi-elastic response from a single quartz capillary filled with water with reasonable data obtained within a run of less than a quarter of an hour.

We’d like to thank again all the participants who made this workshop a lively and interesting event. The friendly and effective contribution of Ms Alison Mader and Mr Serge Claisse in the practical organization merits our warmest thanks. This workshop was possible in good material conditions through the support of the ILL management and NMI3.
Neutrons for Global Energy Solutions
Bonn, 26 - 29 September 2010

www.neutron-eu.net/energy

Sponsored by:

Science & Technology Facilities Council
ISIS

Integrated Infrastructure Initiative for Neutron Scattering and Muon Spectroscopy
NMI3 project supported by the European Commission under the 7th Framework Programme INFRA 2008 - 1.1. Bottom up approach integrating activities in all scientific and technological fields. Research Infrastructures action. Contract No: 226507- NMI3
Imaging and life sciences applications of new light sources

Aim of the workshop is to discuss the possible biological and biomedical uses of the new light sources that are under construction or being considered for construction in Italy, in the UK and in Europe. A selected arena of interested national and international users will be introduced to the potential of new light sources with respect to novel experimentations in the life sciences field, also as a means of advising institutional investors and facilities managers on the relevance of an appropriate support to these developments.

This workshop follows a similar event held in March 2009 at the British Embassy in Rome, originated from the fruitful collaboration between Italian and British Universities. The workshop is organized by the Italian Embassy in London in cooperation with CNR and INFN in Italy, and with the STFC and Diamond Light Source in the United Kingdom. It is promoted by the SPARX Project (under construction at the University campus of Roma “Tor Vergata”), by the British New Light Source project and by the ESRF, and is sponsored by the Italian Ministry of Research and by the Lazio Region.

An Italy-UK workshop
26 March 2010

The Italian Cultural Institute
39 Belgrave Square, London SW1X 8NX

Science Office Italian Embassy:
14 Three kings Yard, London W1K 4EH
Phone: +44 (0) 20 7312 2254
e-mail: scientifico.amblondra@esteri.it
<table>
<thead>
<tr>
<th>Time</th>
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<tbody>
<tr>
<td>9:00</td>
<td>Registration and refreshments</td>
</tr>
<tr>
<td>9:30</td>
<td><strong>Welcome Address</strong></td>
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<tr>
<td></td>
<td>The Italian Ambassador to the UK</td>
</tr>
<tr>
<td></td>
<td><strong>Introductory Remarks</strong></td>
</tr>
<tr>
<td></td>
<td>Jon Marangos, Imperial College</td>
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<tr>
<td>10:00</td>
<td><strong>Keynote Address</strong></td>
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<tr>
<td></td>
<td>Gerhard Materlik, Diamond Light Source</td>
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<td></td>
<td><em>Visions for future light source science</em></td>
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<tr>
<td>10:25</td>
<td>Fulvio Parmigiani (Univ. Trieste, Italy)</td>
</tr>
<tr>
<td></td>
<td><em>Exploring the Science Frontiers with the FERMI@Elettra Free Electron Laser</em></td>
</tr>
<tr>
<td>10:50</td>
<td>Richard Walker (Diamond)</td>
</tr>
<tr>
<td></td>
<td><em>The design of New Light Source</em></td>
</tr>
<tr>
<td>11:15</td>
<td>Coffee break</td>
</tr>
<tr>
<td>11:35</td>
<td>Silvia Morante (University of Roma Tor Vergata)</td>
</tr>
<tr>
<td></td>
<td><em>SPARCX-FEL Project: the Bio-Science case</em></td>
</tr>
<tr>
<td>12:00</td>
<td>David Klug (Imperial College)</td>
</tr>
<tr>
<td></td>
<td><em>2D FIR measurements of proteins using high power multi-colour THz beams</em></td>
</tr>
<tr>
<td>12:25</td>
<td>Anton Barty (DESY)</td>
</tr>
<tr>
<td></td>
<td><em>New imaging at FLASH</em></td>
</tr>
<tr>
<td>12:50</td>
<td>Lunch</td>
</tr>
<tr>
<td>14:10</td>
<td>Cristina Messa (Univ. Milano Bicocca and IBFM-CNR)</td>
</tr>
<tr>
<td></td>
<td><em>Diagnostic molecular imaging: a research tool ready for clinical application</em></td>
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<tr>
<td>14:35</td>
<td>Ralf Menk (ELETTRA)</td>
</tr>
<tr>
<td></td>
<td><em>New R&amp;D imaging technique available for cancer research</em></td>
</tr>
<tr>
<td>15:00</td>
<td>tbd</td>
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<tr>
<td></td>
<td><em>CFEL - Imaging and time resolved measurements</em></td>
</tr>
<tr>
<td>15:25</td>
<td>Guido Cavaletti (Università di Milano Bicocca)</td>
</tr>
<tr>
<td></td>
<td><em>Nanomedicine in Biomedical Science</em></td>
</tr>
<tr>
<td>15:50</td>
<td>Round Table and discussion session</td>
</tr>
<tr>
<td>16:30</td>
<td>Close</td>
</tr>
</tbody>
</table>

Attendance to the workshop is free.
The European neutron community is currently working to develop plans for the European Spallation Source (ESS), a 5 MW long-pulse spallation neutron source, and the SNS in the U.S. is currently developing plans for a second target station (STS) operating in the long-pulse mode at ~1 MW. This workshop provided an opportunity for the U.S. and European neutron communities to pool resources to develop a better understanding of what might be possible with neutron beam instrumentation optimized for operation at such high-power long-pulse spallation neutron sources, and to look at optimization of such instrumentation. It also placed the instrument designers in close contact with the source designers, to develop a dialog that should lead to better optimization of the overall performance for science at these facilities. Carla Andreani organized excellent local arrangements for the workshop, which was held August 26-28 at the Villa Mondragone in Frascati, Italy. The facilities and atmosphere at the Villa Mondragone and at the lodging in the Villa Tuscolana were conducive to many lively discussions among the ~60 attendees from 20 different institutions. The first morning of the workshop was taken up with a plenary session containing a series of short presentations designed to set the stage for the working discussions to follow. Colin Carlile summarized the status of the ESS project, for which Lund, Sweden is the preferred site. The ESS group headquartered at Lund is now proceeding to gather agreements from partnering countries and beginning to revisit the optimization of the source.
parameters, the facility design, and the neutron scattering instrumentation for this facility, via an international consortium of expertise. The current reference design for the ESS is a 5 MW, 16.7 Hz long-pulse facility producing 2 ms long proton pulses. The STS status was summarized by Kent Crawford. Early in 2009 SNS received approval from the U.S. Department of Energy to begin to develop a conceptual design for the STS, and STS conceptual development has been underway since then. Present plans are for the STS to be a 20 Hz, ~1 MW long-pulse facility utilizing ~1 ms long proton pulses. Under an optimistic scenario, the STS could be completed in 2019.

This workshop was intended to build on the work already done at or in conjunction with three earlier long-pulse instrumentation workshops, so the next two presentations summarized the results of those earlier workshops. Kim Lefmann presented a short summary of the work done at the European long-pulse instrumentation workshops held at Rencurel, (September, 2006) and at Ven, Sweden (October, 2008), and Kent Crawford summarized the long-pulse instrumentation workshop held at the SNS (February, 2007) to investigate the opportunities for instrumentation at the STS. To facilitate inclusion of lessons-learned information from other facilities in the thinking at this workshop, the status and recent accomplishments of the ISIS second target station, the SNS facility, and the neutron scattering facility at J-PARC were summarized by Sean Langridge, Kent Crawford, and Masa Arai, respectively. All three also presented some of the lessons learned in the construction and operation of their respective facilities and instruments. Finally, Feri Mezei reminded the working groups of some of the fundamentals for instrumentation at long-pulse sources, and some of the constraints on optimization of those sources.

The bulk of the workshop was devoted to working group discussions. These working group topics were: diffraction and imaging, including single-crystal diffraction, powder, total scattering, liquids diffraction, engineering diffraction, and imaging; SANS and USANS; reflectometry; Larmor techniques including spin-echo; TOF spectroscopy; and sources. As is always the case, the various working groups owe their successes to the efforts of the group chairmen, who made certain that all the desired topics were addressed while keeping the discussions focused and on track.

The diffraction group was chaired by Laurent Chapon (ISIS). This group found that for conventional modest-to-high resolution pulsed source TOF diffractometers (powder or single crystal), the long-pulse sources do not offer data rate gains relative to short-pulse spallation source instruments commensurate with the higher power they provide. This is because at the long-pulse source the source pulse must be significantly shortened by means of a pulse-shaping neutron chopper in order to achieve the desired resolution for these instruments. However, variation of the pulse width selected with this chopper can be used to trade resolution for intensity, making the long-pulse instrument much more versatile than its short-pulse counterpart. This group also proposed a concept for a novel hybrid diffractometer with the potential to make much better use of the full neutron pulse from the long-pulse source. This concept would use multiple crystal monochromators (or analyzers) to select a series of different discrete wavelengths incident on

The source and TOF spectroscopy groups working closely together. (photo courtesy of Axel Steuwer)
(or diffracted from) the sample, and would then make use of the time structure of the neutron production to separate the diffraction spectra from the different wavelengths. This concept was too complex for detailed assessment in the short time available at the workshop, but participants agreed to pursue this further off-line. The SANS group, chaired by Albrecht Wiedenmann (ILL), laid out the parameters for a “flagship” SANS instrument for the long-pulse sources. This instrument would be optimized for smaller sample sizes than is typical in current SANS instrument designs, and when placed at the ESS it was estimated to provide gain factors ranging from 1 to 50 relative to D22 at ILL (a factor of ~5 less at the STS). This instrument would have polarized beam capabilities and focusing capabilities to be used for very small samples. It would also have spin-echo coils installed to provide SESANS capabilities when needed for the study of long-scale correlations.

The reflectometry working group was chaired by Sean Langridge (ISIS). This group concluded that reflectometers can use the full pulse of a long-pulse source effectively for most experiments. Instruments would need to be somewhat longer than at most present short-pulse sources, but this will have the advantage of placing them in regions of lower background and where there is more space around the instrument for ease of operation and flexibility of ancillary equipment. They estimated that it should be possible to measure reflectivities down to ~10^{-8} from a 1 cm² sample with properly optimized instruments. This group also pointed out that future experiments are likely to look for more subtle effects than is the case with many present experiments. This will require much better understanding and/or control of the systematic errors from the instruments. It will also require very robust analysis packages. Simulations incorporating more realistic instrumental properties will be important. (Note: these latter statements probably apply to other types of instruments as well, rather than just to reflectometers.)

Michael Monkenbusch (Fz. Juelich) chaired the working group on spin-echo and Larmor techniques. This group considered a number of different techniques, and concluded that the only ones likely to merit dedicated beamlines at the new long-pulse sources are high-resolution NSE using precession magnets and wide-angle NSE using precession magnets. The group estimated that a high-resolution NSE instrument at the 5 MW ESS would provide a factor of 3-5 gain in data rate compared to the ILL instruments. The group also considered that high-resolution SANS with NSE (SESANS) and grazing-incidence measurements with NSE (SERGIS, GINSE) are well-developed techniques that should be supplied as “drop-in” capabilities on other instruments. Techniques felt to be still experimental, requiring development and/or new equipment capabilities, include resonant NSE, MIEZE, NSE with time-varying flippers, 3D polarimetry in combination with NSE, and spin-based beam modulation (Drabkin flippers, choppers).

The working group on TOF spectroscopy, chaired by Garrett Granroth (SNS), noted that a considerable amount of work had already been done in this area at the Rencurel, STS, and Ven workshops. The group reaffirmed that a “flagship” instrument should be roughly 100 m long using a pulse-shaping chopper to produce ~100 μs neutron pulses, and should use repetition-rate multiplication. (These parameters are based on ESS with a 2 ms long source pulse.)
Such an instrument at ESS, using repetition-rate multiplication, should be able to produce data rates 100 times those for IN5 at ILL at the same resolution. Showing the flexibility possible with the long-pulse approach, the group indicated that by tightening the pulse-width allowed through the pulse-shaping chopper to ~5 µs the instrument could provide resolution that is twice as good as that at IN5, with still somewhat better data rate than at IN5. Other instruments considered by this group included a thermal spectrometer and a high resolution backscattering spectrometer. The group concluded that the optimization of concepts for the backscattering spectrometer still required considerable further study. The case of the thermal spectrometer led to much discussion, and in the end the group concluded that these high-power long-pulse sources should probably have both chopper spectrometers and triple-axis spectrometers to cover the full range of science with thermal neutrons. One of the highlights of the workshop was the presence of a number of experts from different laboratories in the fields of neutronics and source development. These experts made up a separate working group on sources, chaired by Guenter Muhrer (Lujan Center), that carried out extensive joint discussions with each of the different instrumentation working groups. The outcome was a summary of the desired source capabilities including figures of merit for each type of instrument. This group then met on its own to assess this information and the directions that might be followed in trying to optimize facility performance for such a wide variety of instruments. This workshop provided a timely stimulus to thinking about the long-pulse instrumentation that will be needed for these future sources. Previously developed concepts were refined, some new concepts were identified for further exploration, and a number of longer-term optimization studies needing simulations were identified and directions were established for these studies. It was made clear that many future studies will be looking at more subtle effects, so the community will have to develop a better understanding than we now have of systematic effects introduced by the instruments and measurement and analysis techniques. The workshop also sparked a renewed awareness of some of the more subtle advantages of the proposed long-pulse, low-repetition-rate sources, including great flexibility in tailoring resolution to experiments on a given instrument, and longer flight paths leading to lower backgrounds and more working space. Additional studies will be required to understand and utilize the full impact of these capabilities. This broadened community awareness of the issues and opportunities associated with the proposed new sources should lead to productive collaborations to address many of these areas. It was also very valuable to have source experts, instrumentation experts, and simulation experts together at the workshop, and this combination led to a better understanding of the figures of merit appropriate for source optimization for various types of instrumentation. All three groups will need to work in close collaboration to achieve the optimum performance at the new sources.

Further information, including summary presentations from the working groups, can be found at the workshop web site http://neutrons.ornl.gov/workshop/.

The 12th National School on Neutron and X-ray Scattering
will be held June 12-26, 2010, at Argonne National Laboratory and Oak Ridge National Laboratory. The application deadline is March 8, 2010.

The main purpose of the National School on Neutron and X-ray Scattering is to educate graduate students on the utilization of major neutron and x-ray facilities. Lectures, presented by researchers from academia, industry, and national laboratories, will include basic tutorials on the principles of scattering theory and the characteristics of the sources, as well as seminars on the application of scattering methods to a variety of scientific subjects. Students will conduct short experiments at Argonne’s Advanced Photon Source (APS) and Oak Ridge’s Spallation Neutron Source (SNS) and High Flux Isotope Reactor (HFIR) facilities to provide hands-on experience for using neutron and synchrotron sources.

Additional details about the School, along with electronic registration, are provided through the Argonne Division of Educational Programs website at http://www.dep.anl.gov/nx.
Call for Proposal [Deadlines for proposal submission]

Neutron Sources
http://pathfinder.neutron-eu.net/idb/access

- **BNC**
  May 15 and October 15

- **BENSC**
  1 March and 1 September annually
  http://www.helmholtz-berlin.de/userservice/neutrons/user-info/call-for-proposals_en.html#c63361

- **GeNF - Geesthacht Neutron Facility**
  At any time during 2010
  www.gkss.de/index_e.js.html

- **HFIR**
  March 3, 2010
  http://neutrons.ornl.gov/users/user_news.shtml

- **ILL**
  February 15, 2010
  www.ill.eu/users/experimental-programme/

- **ISIS**
  April 16, 2010
  http://www.isis.stfc.ac.uk/index.html

- **JCNS FZ-Jülich**
  January 29, 2010
  www.jcns.info/jcns_proposals/

- **LLB - Laboratoire Léon Brillouin**
  May 1, 2010
  http://pathfinder.neutron-eu.net/idb/access

- **NPL - Neutron Physics Laboratory**
  To be announced, 2010
  http://pathfinder.neutron-eu.net/idb/access

- **SINQ – Swiss Spallation Neutron Source**
  To be announced, 2010
  http://pathfinder.neutron-eu.net/idb/access

- **SNS**
  March 3, 2010
  http://neutrons.ornl.gov/users/user_news.shtml

Synchrotron Radiation Sources
www.lightsources.org/cms/?pid=1000336#byfacility

- **AS - Australian Synchrotron**
  June 21, 2010
  http://www.lightsources.org/cms/?pid=1000128
Call for Proposal

From January 15 to March 01, 2010

**BESSY**
http://www.bessy.de/boat/www/

Proposals are evaluated twice a year

**BSRF - Beijing Synchrotron radiation Facility**
www.ihep.ac.cn/bsrf/english/userinfo/beamtime.htm

January-April Cycle: September 30
May-August Cycle: January 31
September-December Cycle: May 31

**CFN - Center for Functional Nanomaterials**
www.bnl.gov/cfn/user/proposal.asp

At any time during 2010

**CHESS - Cornell High Energy Synchrotron Source**
www.chess.cornell.edu/proposals/index.htm

for crystallography beamlines 1st March, 2010
for other beamlines February 25, 2010

**CLLS – Canadian Light Source**
http://www.lightsource.ca/uso/call_proposals.php

February 2010

**DIAMOND - Diamond Light Source**
www.diamond.ac.uk/ForUsers/Welcome

March 15th, 2010

**ELETTRA**
https://vuo.elettra.trieste.it/pls/vuo/guest.startup

1st June, 2010

**FELIX - Free Electron Laser for Infrared experiments**
www.rijnh.nl/research/guthz/felix_felice/

FLASH: to be announced, 2010

DORIS III: March 1, 2010

**HASYLAB - Hamburger Synchrotronstrahlungslabor at DESY**
http://hasylab.desy.de/user_info/write_a_proposal/2_deadlines/index_eng.html

Jan 31, 2010

**NSLS - National Synchrotron Light Source**
https://pass.nsls.bnl.gov/deadlines.asp

January 30, 2010

**NSRRC - National Synchrotron radiation Research Center**
www.nsrrc.org.tw/

To be announced

**PF – Photon Factory**
www.nsrrc.org.tw

February 15, 2010

**SLS - Swiss Light Source**

1st February, 2010

**SRC - Synchrotron Radiation Center**
www.lightsources.org/cms/?pid=1000336

Macromolecular Crystallography 1st April, 2010

**SSRL - Stanford Synchrotron Radiation Laboratory**
www.ssrl.slac.stanford.edu/users/user_admin/deadlines.html

X-ray/VUV 1st June, 2010
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<th>Date</th>
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<td><strong>January 29, 2010</strong></td>
<td>Hamburg (Germany)</td>
<td><strong>HASYLAB Users’ Meeting</strong></td>
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<td><strong>February 18-22, 2010</strong></td>
<td>San Diego, CA (USA)</td>
<td><strong>USAAAS Annual Meeting</strong></td>
<td><a href="http://www.aaas.org/meetings/future_mtgs/">http://www.aaas.org/meetings/future_mtgs/</a></td>
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<td><strong>February 20-27, 2010</strong></td>
<td>Planneralm, Austria</td>
<td><strong>25th Workshop on Novel Materials and Superconductors: Computers in Material Sciences</strong></td>
<td><a href="http://www.wien2k.at/theochem/planneralm/">http://www.wien2k.at/theochem/planneralm/</a></td>
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<td>SNI 2010: Deutsche Tagung für Forschung mit Synchrotronstrahlung, Neutronen und Ionenstrahlen an Grossgeräten</td>
<td>Berlin, Germany</td>
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<td><a href="http://www.helmholtz-berlin.de/events/sni2010/">http://www.helmholtz-berlin.de/events/sni2010/</a></td>
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<td>20th RAU - LNLS Annual Users Meeting</td>
<td>Campinas, Brazil</td>
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<td><a href="http://rau.lnls.br/">http://rau.lnls.br/</a></td>
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<td>LCLS AMO First Science Results Workshop</td>
<td>Menlo Park, CA</td>
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<td><a href="http://lcls.slac.stanford.edu/">http://lcls.slac.stanford.edu/</a></td>
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<td>31st Berlin School on Neutron Scattering</td>
<td>Berlin, Germany</td>
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<td>ICANS-XIX: The 19th Meeting of the International Collaboration on Advanced Neutron Sources</td>
<td>Grindelwald, Switzerland</td>
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<td><a href="http://icans.web.psi.ch/">http://icans.web.psi.ch/</a></td>
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<td>The American Physical Society March Meeting</td>
<td>Portland, OR</td>
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<td><a href="http://www.aps.org/meetings/march/index.cfm">http://www.aps.org/meetings/march/index.cfm</a></td>
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<td>American Chemical Society Spring 2010 National Meeting &amp; Exposition</td>
<td>San Francisco, CA</td>
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February 24-26, 2010

February 22-23, 2010

February 22-24

February 25-28, 2010

March 3-5, 2010

March 8-12, 2010

March 11-19, 2010

March 17-19, 2010

March 15-19, 2010

March 21-25, 2010

March 22-26, 2010
March 25-26, 2010  Grenoble, France
HERCULES XX: HERCULES Symposium

March 28 - April 1, 2010  Frankfurt, Germany
Fourth Seeheim Conference on Magnetism
http://www1.tu-darmstadt.de/magnetism/

April 5-9, 2010  Istres, France
Simulation of neutron scattering techniques: From Beamline Optics to Virtual Experiments
http://neutron.neutron-eu.net/n_news/n_calendar_of_events/n-events-2010/1856

April 5-9, 2010  San Francisco, CA (USA)
2010 MRS Spring Meeting
Materials Research Society Spring Meeting
http://www.mrs.org/s_mrs/sec.asp?CID=16773&DID=216957

April 15-16, 2010  Baton Rouge, LA (USA)
LSU CAMD Annual User Meeting

April 19-23, 2010  Barcelona, Spain
E2C-2010: European Energy Conference
http://www.e2c-2010.org/

May 3-6, 2010  Rigi Kulm, Switzerland
MaMaSELF 2010: 3rd Annual Status Meeting
http://diffraction.web.psi.ch/mamaself-rigi-ch.htm

May 3-7, 2010  Tenerife España
Third Annual School on Advanced Neutron Diffraction Data Treatment using the FULLPROF SUITE (FPSCHOOL)
Link to the 2nd edition

May 17-21, 2010  Monte Verita, Locarno (Switzerland)
Advanced Phase Measurement Methods in Optics and Imaging
http://phasemeas2010.epfl.ch/

May 19-21, 2010  Barcelona, Spain
NMI3 General Meeting 2010
http://neutron.neutron-eu.net/n_nmi3fp7
<table>
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<th>Location</th>
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<td>May 31 - June 2, 2010</td>
<td>Amsterdam, The Netherlands</td>
<td><strong>ICCS 2010: Tenth International Conference on Computational Science</strong></td>
<td><a href="http://www.iccs-meeting.org/">http://www.iccs-meeting.org/</a></td>
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<td>June 8-11, 2010</td>
<td>Rostock-Warnemünde (Germany)</td>
<td><strong>COHERENCE 2010</strong></td>
<td>International Workshop on Phase Retrieval and Coherent Scattering</td>
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Neutron Scattering

WWW SERVERS IN THE WORLD
http://idb.neutron-eu.net/facilities.php

BNC - Budapest Research reactor
Type: Swimming pool reactor, 10 MW
Phone: +36/1/392-2222
Phone e fax: +36/1/395-9162
Email: tozser@sunserv.kfki.hu
http://www.kfki.hu/brr/indexen.htm

BENSC - Berlin Neutron Scattering Center
Phone: +49-30 / 80 62 - 0
Fax: +49-30 / 80 62 - 21 81
Email: info@helmholtz-berlin.de
http://www.helmholtz-berlin.de/

FLNP - Frank Laboratory of Neutron Physics
Phone: (7-49621) 65-657
Fax: (7-49621) 65-085
E-mail: belushk@nf.jinr.ru http://flnp.jinr.ru/25/

FRG-1
Type: Swimming Pool Cold Neutron Source
Phone: +49 (0)152 87-0
Fax: +49 (0)41 52 87-1403
Email: reinhard.kampmann@gkss.de
http://www.gkss.de/about_us/contact/research_reactor/index.htm

FRG-2
Forschungszentrum Jülich GmbH
Type: DIDO(heavy water), 23 MW
http://www.fz-juelich.de/iff/wns/

FRM II
Type: Compact 20 MW reactor
Phone: +49 (0) 89 289 14965
Fax: +49 (0) 89 289 14995
Email: Winfried.Petry@frm2.tum.de

HFNIR
ORNL, Oak Ridge, USA
Phone: (865)574-5231
Fax: (865)576-7747
Email: ns_user@ornl.gov
http://neutrons.ornl.gov

HIFAR
Phone: +61 2 9717 3111
ANSTO Facsimile: + 61 2 9543 5097
Email: enquiries@ansto.gov.au
http://www.ansto.gov.au

ILL
Phone: +33 4 7620 7179
Fax: +33 4 76483906
Email: cico@ill.fr and sco@ill.fr
http://www.ill.eu

IPNS - Intense Pulsed Neutron at Argonne
Phone: 630/252-7820
Fax: 630/252-7722
for proposal submission by e-mail send to cpeters@anl.gov
or mail/fax to IPNS Scientific Secretary, Building 360
http://www.pns.anl.gov/

JCNS
Juelich Centre for Neutron Science Forschungszentrum Juelich,
D-52425 Juelich, Germany
E-mail: neutron@fz-juelich.de
http://www.jcns.info

JRR-3M
Fax: +81 292 82 59227
Phone: JAERI24596
Email: www-admin@www.jaea.go.jp

Notiziario Neutroni e Luce di Sincrotrone - Vol. 15 n. 1
JEIP-II Reactor
Type: D2O moderated 3.5% enriched UO2 fuel
Phone: +47 63 806000, 806275
Fax: +47 63 816356
Email: kjell.bendiksen@ife.no

KENS
Institute of Materials Structure Science
High Energy Accelerator research Organisation
1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305-0801, JAPAN
Email: kens-pac@mnl.kek.jp
http://neutron-www.kek.jp/index_e.html

KUR - Kyoto University Research Reactor Institute
Kumatori-cho Sennan-gun, Osaka 590-0494, Japan
Phone: +81-72-451-2300
Fax: +81-72-451-2600
http://www.ri.rikyo-u.ac.jp/en/

LANSCE
Phone: 505-665-1010
Fax: 505-667-8830
Email: lansce_users@lanl.gov
Email: tichavez@lanl.gov
http://lansce.lanl.gov/

LLB
Type: Reactor
Flux: 3.0 x 10^14 n/cm^2/s
Secretariat Europe:
Phone: 0169085417
Fax: 016908261
Email: experience@llb.cea.fr
http://www-llb.cea.fr

NFL - Studsvik Neutron Research Laboratory
Uppsala University - Studsvik Nuclear AB, Stockholm, Sweden
Type: swimming pool type reactor, 50 MW, with additional reactor 1 MW
http://cordis.europa.eu/data/PROJ_FPS/ACTIONEqDnDSESSIONEq
112302005919ndDOCeq4269ndTBLeqEN_PROJ.htm

NCNR - NIST Center for Neutron Research
Phone: (301) 975-6210
Fax: (301) 869-4770
Email: Robert.dimeo@nist.gov http://rrdjazz.nist.gov

NPL – NRI
Type: 10 MW research reactor
Phone: +420 2 20941177 / 66173428
Fax: +420 2 20941155
Email: krz@ujv.cz and brv@nri.cz
http://neutron.ujf.cas.cz/

NRU - Chalk River Laboratories
Phone: 613-584-8293
Fax: 613-584-4040
http://neutron.nrc-cnrc.gc.ca/home_e.html

RID - Reactor Institute Delft (NL)
Type: 2MW light water swimming pool
Phone: +31 15 27 87774
Fax: +31 15 27 82655
E-mail: L.Hagman@tudelft.nl
http://www.ri.tudelft.nl/live/pagina.jsp?id=b15d7df9-7928-441e-b45d-
6ece78d6b0e&lang=en

SINQ
Type: Steady spallation source
Phone: +41 56 310 4666
Fax: +41 56 3103294
Email: sinq@psi.ch http://sinq.web.psi.ch

SNS - Spallation Neutron Source
Phone: 865.574.1301
Fax: (865) 241-5177
Email: ekkebusae@ornl.gov
http://neutrons.ornl.gov
Synchrotron Radiation Sources

WWW SERVERS IN THE WORLD
www.lightsources.org/cms/?pid=1000098

ALBA - Synchrotron Light Facility
Phone: +34 93 592 43 00
Fax: +34 93 592 43 01
http://www.cells.es/

ALS - Advanced Light Source
Phone: 510.486.7745
Fax: 510.486.4773
Email: alsuser@lbl.gov
http://www-als.lbl.gov/als

ANKA
Phone: +49 (0)7247 / 82-6188
Fax: +49-(0)7247 / 82-8677
Email: info@fzk.de
http://ankaweb.fzk.de/

APS - Advanced Photon Source
Phone: (630) 252-2000
Fax: +1 708 252 3222
Email: fenner@aps.anl.gov
http://www.aps.anl.gov/

AS - Australian Synchrotron
Phone: +61 3 9655 3315
Fax: +61 3 9655 8666
Email: contact.us@synchrotron.vic.gov.au

BESSY - Berliner Elektronenspeicherring Gesellschaft für Synchrotronstrahlung
Phone: +49 (0)30 6392-2999
Fax: +49 (0)30 6392-2990
Email: info@bessy.de
http://www.bessy.de/

BSRF - Beijing Synchrotron Radiation Facility
Phone: +86-10-68235125
Fax: +86-10-6822013
Email: houbz@mail.ihep.ac.cn

CAMD - Center Advanced Microstructures & Devices
Phone: +1 (225) 578-8887
Fax: +1 (225) 578-6954
Email: leeann@lsu.edu
http://www.camd.lsu.edu/

CANDLE - Center for the Advancement of Natural Discoveries using Light Emission MODIFIC.
Phone/Fax: +374-1-629806
Email: baghryan@asl.candle.am
http://www.candle.am/index.html

CESLAB - Central European Synchrotron Laboratory
Phone: +420-541517500
Email: kozubek@ibp.cz
http://www.synchrotron.cz/synchrotron/Central_EuropeanSynchrotronLaboratory_EN.html

CFN - Center for Functional Nanomaterials
Phone: +1 (631) 344-6266
Fax: +1 (631) 344-3093
Email: cfnuser@bnl.gov
http://www.bnl.gov/cfn/

CHESS - Cornell High Energy Synchrotron Source
Phone: 607-255-7163
Fax: 607-255-9001
http://www.chess.cornell.edu/

CLIO - Centre Laser Infrarouge d’Orsay
email: accueil-clio@lcp.u-psud.fr
http://clio.lcp.u-psud.fr/clio_eng/clio_eng.htm

CLS - Canadian Light Source
Phone: (306) 657-3500
Fax: (306) 657-3535
Email: clsuo@lightsource.ca
http://www.lightsource.ca/

CNM - Center for Nanoscale Materials
Phone: 630.252.6952
Fax: 630.252.5739
http://nano.anl.gov/facilities/index.html
CTST - UCSB Center for Terahertz Science and Technology
University of California, Santa Barbara (UCSB), USA
http://sbfel3.ucsb.edu/

DAFNE Light
INFN-LNF
Phone: +39 06 94031
Fax: +39 06 9403 2582
http://www.lnf.infn.it/

DELSY - Dubna EElectron SYnchrotron
Phone: + 7 09621 65 059
Fax: + 7 09621 65 891
Email: post@jinr.ru
http://www.jinr.ru/delsy/

DELT A - Dortmund Electron Test Accelerator
FELICITA I (FEL)
Fax: +49-(0)231-755-5383
http://www.delta.uni-dortmund.de/index.php?id=2&L=1

DFELL - Duke Free Electron Laser Laboratory
Phone: 1 (919) 660-2666
Fax: +1 (919) 660-2671
Email: beamtime@fel.duke.edu
http://www.fel.duke.edu/

Diamond Light Source
Phone: +44 (0)1235 778000
Fax: +44 (0)1235 778499
Email: useroffice@diamond.ac.uk
http://www.diamond.ac.uk/default.htm

ELETTRA - Synchrotron Light Laboratory
Phone: +39 40 37581
Fax: +39 (040) 938-0902
http://www.elettra.trieste.it/

ELS A - Electron Stretcher Accelerator
Phone: +49-228-735926
Fax: +49-228-733620
Email: roy@physik.uni-bonn.de
http://www-elsa.physik.uni-bonn.de/elsa-facility_en.html

ESRF - European Synchrotron Radiation Lab.
Phone: +33 (0)4 7688 2000
Fax: +33 (0)4 7688 2020
Email: useroff@esrf.fr
http://www.esrf.eu/

FELBE - Free-Electron Lasers at the ELBE radiation source at the FZR/Dresden
Phone: +49 351 260 - 0
Fax: +49 351 269 - 0461
E-Mail: kontakt@fzd.de
http://www.fzd.de

FEL I X - Free Electron Laser for Infrared experiments
Phone: +31-30-6096999
Fax: +31-30-6031204
Email: B.Redlich@rijnh.nl
http://www.rijnh.nl/felix/

FOUNDRY - The Molecular Foundry
1 Cyclotron Road Berkeley, CA 94720, USA
http://foundry.lbl.gov/index.html

HAS YLAB - Hamburger Synchrotronstrahlungslabor
DORIS III, PETRA II / III, FLASH
Phone: +49 40 / 8998-2304
Fax: +49 40 / 8998-2020
Email: HASYLAB@DESY.de
http://hasylab.desy.de/

HSRC - Hiroshima Synchrotron Radiation Center HISOR
Phone: +81 82 424 6293
Fax: +81 82 424 6294
http://www.hsrc.hiroshima-u.ac.jp/english/index-e.htm

Ifel
Phone: +81-(0)72-897-6410
http://www.fel.eng.osaka-u.ac.jp/english/index_e.html
INDUS-1 / INDUS-2
Phone: +91-731-248-8003
Fax: 91-731-248-8000
Email: rvn@cat.ernet.in
http://www.cat.ernet.in/technology/accel/indus/index.html
http://www.cat.ernet.in/technology/accel/atdhome.html

IR FEL Research Center - FEL-SUT
Phone: +81 4-7121-4290
Fax: +81 4-7121-4298
Email: felsut@rs.noda.sut.ac.jp
http://www.rs.noda.sut.ac.jp/~felsut/english/index.htm

ISA Institute for Storage Ring Facilities - ASTRID-1
Phone: +45 8942 3778
Fax: +45 8612 0740
Email: fyssp@phys.au.dk
http://www.isa.au.dk/

ISI-800
Phone: +(380) 44 424-1005
Fax: +(380) 44 424-2561
Email: metall@imp.kiev.ua

Jlab - Jefferson Lab FEL
Phone: (757) 269-7100
Fax: (757) 269-7848
http://www.jlab.org/FEL

Kharkov Institute of Physics and Technology – Pulse stretcher/Synchrotron Radiation
Phone: +38 (057) 335-35-30
Fax: +38 (057) 335-16-88
http://www.kipt.kharkov.ua/indexe.html

KSR - Nuclear Science Research Facility - Accelerator Laboratory
Fax: +81-774-38-3289
http://wwwal.kuicr.kyoto-u.ac.jp/www/index-e.html

KSRS - Kurchatov Synchrotron Radiation Source Siberia-1 / Siberia-2
Phone: 8-499-196-96-45
http://www.lightsources.org/cms/?pid=1000152
http://www.kiae.ru/ (in Russian)

LCLS - Linac Coherent Light Source
Phone: +1 (650) 926-3191
Fax: +1 (650) 926-3600
Email: knotts@ssrl.slac.stanford.edu
http://www-ssrl.slac.stanford.edu/lcls/

LNLS - Laboratorio Nacional de Luz Sincrotron
Phone: +55 (0) 19 3512-1010
Fax: +55 (0)19 3512-1004
Email: sau@lnls.br
http://www.lnls.br/lnls/cgi/cgilua.exe/sys/start.htm?UserActiveTemplate=lnls%5F2007%5Fenglish&tpl=home

MAX-Lab
Phone: +46-222 9872
Fax: +46-222 4710
http://www.maxlab.lu.se/

Medical Synchrotron Radiation Facility
Phone: +81-(0)43-251-2111
http://www.nirs.go.jp/ENG/index.html

MLS - Metrology Light Source
Physikalisch-Technische Bundesanstalt
Phone: +49 30 3481 7312
Fax: +49 30 3481 7550
Email: Gerhard.Ulm@ptb.de
http://www.ptb.de/mls/

NSLS - National Synchrotron Light Source
Phone: +1 (631) 344-7976
Fax: +1 (631) 344-7206
Email: nslsuser@bnl.gov http://www.nsrl.bnl.gov/

NSRL - National Synchrotron Radiation Laboratory
Phone: +86-551-3601989
Fax: +86-551-514078
Email: zdh@ustc.edu.cn
http://www.nsrl.ustc.edu.cn/en/
NSRRC - National Synchrotron Radiation Research Center
Phone: +886-3-578-0281
Fax: +886-3-578-9816
Email: user@nsrrc.org.tw
http://www.nsrrc.org.tw/

NSSR - Nagoya University Small Synchrotron Radiation Facility
Phone: +81-(0)43-251-2111
http://www.nagoya-u.ac.jp/en/

PAL - Pohang Accelerator Laboratory
San-31 Hyoja-dong Pohang Kyungbuk 790-784, Korea
Email: ilguya@postech.ac.kr
http://pal.postech.ac.kr/eng/index.html

PF - Photon Factory
Phone: +81 (0)-29-879-6009
Fax: +81 (0)-29-864-4402
Email: users.office2@post.kek.jp
http://pfwww.kek.jp/

PSLS - Polish Synchrotron Light Source
Phone: +48 (12) 663 58 20
Email: mail@synchrotron.pl
http://www.if.uj.edu.pl/Synchro/

Rits Ritsumeikan University SR Center
Phone: +81 (0)77 561-2806
Fax: +81 (0)77 561-2859
Email: d11-www-adm@se.ritsumei.ac.jp
http://www.ritsumei.ac.jp/se/re/SSLS/newpage13.htm

SAGA-LS - Saga Light Source
Phone: +81-942-83-5017
Fax: +81-942-83-5196
http://www.saga-ls.jp/?page=173

SESAME Synchrotron-light for Experimental Science and Applications in the Middle East
E-mail: hhelal@mail.eun.eg

SLS - Swiss Light Source
Phone: +41 56 310 4666
Fax: +41 56 310 3294
Email: slsuo@psi.ch
http://sls.web.psi.ch/view.php/about/index.html

SOLEIL
Phone: +33 1 6935 9652
Fax: +33 1 6935 9456
Email: frederique.fraissard@synchrotron-soleil.fr
http://www.synchrotron-soleil.fr/portal/page/portal/Accueil

SPL - Siam Photon Laboratory
Phone: +66-44-21-7040
Fax: +66-44-21-7047, +66-44-21-7040 ext 211
http://www.sli.or.th/new_eng/

Spring-8
Phone: +81-(0) 791-58-0961
Fax: +81-(0) 791-58-0965
Email: sp8jasri@spring8.or.jp
http://www.spring8.or.jp/en/

SRC - Synchrotron Radiation Center
Phone: +1 (608) 877-2000
Fax: +1 (608) 877-2001
http://www.src.wisc.edu/

SSLS - Singapore Synchrotron Light Source - Helios II
Phone: (65) 6874-6568
Fax: (65) 6773-6734
http://ssls.nus.edu.sg/index.html

SSRC - Siberian Synchrotron Research Centre VEPP3/VEPP4
Phone: +7(3832)39-44-98
Fax: +7(3832)34-21-63
Email: G.N.Kulipanov@inp.nsk.su
http://ssrc.inp.nsk.su/english/loadd.pl?right=general.html
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www.cnr.it/neutronielucedisincrotrone

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