Laboratori Nazionali di Frascati

LNF–11/ 08 (NT)
30 May 2011

COLLABORATIVE RESEARCH FOR A HIGH-RESOLUTION VUV FREE ELECTRON LASER USER FACILITY AT SPARC

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Abstract

Free electron lasers (FELs) are unique sources of tunable coherent radiation, based on the interaction of a relativistic electron beam with a permanent magnetic field. Taking advantage of their characteristics, many scientific applications are possible using these 4th generation powerful sources of radiations.

With its high-quality beam the SPARC FEL designed to work at long wavelengths allows non-linear coherent harmonic generation also in the VUV range. Although other FEL proposals are under discussions in other European facilities in addition to SPARC a few other projects may now offer similar performances: TESLA at Hamburg and FERMI at Trieste.

The document is a proposal to use the radiation emitted by SPARC in the ultraviolet range with a unique beamline to be installed in the LI2FE laboratory based on a high resolution monochromator made available from the STFC Daresbury Laboratory (U.K.).

Published by
Servizio Informazione e Documentazione Scientifica dei LNF
Ufficio Biblioteca e Pubblicazioni

Collaborative research for a high-resolution VUV Free Electron Laser User Facility at SPARC

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The proposal is supported by:

M.R.F. Siggel-King (Daresbury Science and Innovation Campus, U.K.)
G. Contini, P. De Padova, C. Quaresima, T. Prosperi, V. Rossi, S. Turchini (CNR-ISM)
L. Avaldi, P. Bolognesi, R. Flammini, P. Okeeffe, S. Orlando (CNR-IMIP)
M. Benfatto, D. Di Gioacchino, M. Castellano, M. Cestelli Guidi, R. Cimino,
G. Dipirro, M. Ferrario (INFN/LNF)
A. Desio, L. Gambicorti (Universita' di Firenze)
P. Milani, P. Piseri (CIMAINA, Universita' di Milano)
P. Innocenzi (Universita' di Sassari)

Table of Contents

Section A: Project summary

Free electron lasers (FELs) are unique sources of tunable coherent radiation, based on the interaction of a relativistic electron beam with a permanent magnetic field. Taking advantage of their characteristics, many scientific applications are possible using these 4th generation powerful sources of radiations.

FEL projects in the UV-XUV operating range make use of the amplifier configuration in the SASE mode that generates its output from the spontaneous emission created. Indeed, the development of laser oscillators of any type for the VUV and X-ray spectral range suffers from a lack of high-reflective optics at such wavelengths. The development of such optics is non-trivial because of the high peak powers, the spectral range and the tuning capabilities of a FEL source. Actually, to obtain a high gain mode, a FEL necessitates exceptional electron beam performances.

With its high-quality beam the SPARC FEL designed to work at long wavelengths allows non-linear coherent harmonic generation also in the VUV range. Although other FEL proposals are under discussions in other European facilities in addition to SPARC a few other projects may now offer similar performances: TESLA at Hamburg and FERMI at Trieste.

These 4th generation sources will not supersede existing synchrotron radiation sources but will complement their capabilities and meet new emerging user requirements.

The document is a proposal to use the radiation emitted by SPARC in the ultraviolet range with a unique beamline to be installed in the LI^{2}FE laboratory based on a high resolution monochromator made available from the STFC Daresbury Laboratory (U.K.).

Section B: The FEL source.

General layout and SASE performances

SPARC is a single pass free electron laser (FEL) amplifier test facility designed to study the amplification process in different operating conditions. (Fig. 1) The electron beam is provided by a linac composed by three SLAC type accelerating sections with a final maximum beam energy in the present layout of about 180 MeV. [1]

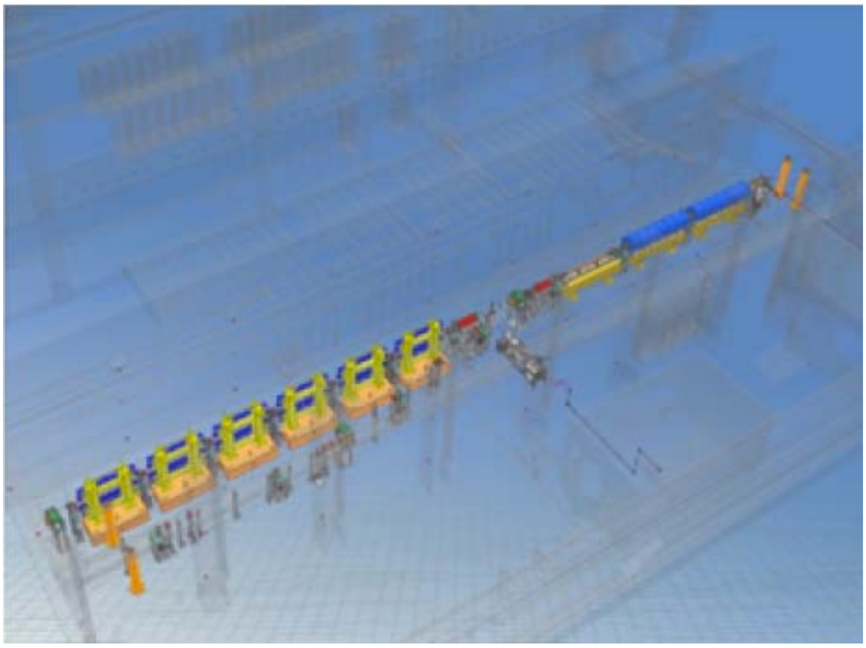

Fig. 1 A bird's eye view of the SPARC FEL facility

The electron beam is generated in a BNL/UCLA/LCLS design, high brightness RF-gun, which was implemented in the first operating phase to study the beam evolution in the drift between the gun and the main linac [2].
These steps were carried out during 2009, with the first SASE FEL spectra obtained in February 2009 and beam compression via velocity bunching with emittance compensation in April 2009. In the summer of 2009 a substantial increase of the extracted radiation from the FEL source was obtained with a longitudinally at top e-beam, by increasing the bunch charge and by anticipating the phase in the gun to reduce the debunching in the first stage of acceleration.
The SPARC undulators were realized by ACCEL Gmbh. They are made of six permanent magnet modules with 75 periods of 2.8 cm each. Actually the system has 77 periods including termination periods not concurring to the amplification process. The undulator gap may be varied in the range 25 to 8.4 mm, limited by the vacuum chamber, corresponding to a maximum undulator parameter K_{MAX} ~2.2 at the minimum gap.
Recently lasing performances obtained at SPARC in the SASE mode have been reported at a wavelength of 500 nm. An overall amplification factor close to 10^7 has been obtained injecting an electron beam with an energy of 151 MeV.
The beam used in the SASE FEL experiment was obtained with a longitudinally flat top laser pulse of 6-8 ps FWHM long. The charge extracted was in the range of 400-450 pC. The gun operated at a gradient of ~105 MV/m resulting in a peak current of 55 A.

Beam energy (MeV)	152.08
Energy Spread $(proj.\ \%)$	4.36810^{-2}
Energy Spread $(slice\ \%)$	1.6710^{-2}
Length (ps)	2.65
Beam current (A)	53
Vertical Emittance $(mm\ mrad)$	2.9
Horizontal Emittance $(mm\ mrad)$	2.5

Table 1 Main beam parameters of the SPARC FEL during the SASE experiment [2]

The SPARC electron beam was characterized by a r.m.s. length of 2.65 ps, a slice energy spread of 1.7 10^{-4} and a transverse emittance of 2.9 (2.5) mm mrad in the vertical (horizontal) plane. The maximum energy collected at the fundamental resonance was 0.01 mJ. The third harmonic energy was measured with all undulators set at resonance at a level of tenths of nJ [2]. Spectra with different number of undulators were measured when the evolution of the spectrum in the SASE regime has been observed. Comparison of simulations made with different programs and experimental data have shown a satisfactory agreement.
The performance of the FEL in these operating conditions was limited by the low beam current and relatively high transverse emittance. Combining velocity bunching and tapering of the undulator allowed to increase the pulse energy by two orders of magnitude (0.1-0.2 mJ) while shortening the radiation pulse to the few hundred of femtoseconds. This was achieved along with suppression of the typical SASE spiking. [3] The beam parameters used in this experiment are listed in Table 2

Beam energy	MeV	115.2
Rel. energy spread	slice/proj.%	0.6/1.15
Proj. emittances (x/y)	mm-mrad	2.7/3.0
Rms length	rms-ps	0.42
Peak current	A	380
$<\beta_x>=<\beta_y>$	m	1.5

Table 2 Main beam parameters of the SPARC FEL during the SASE FEL with chirped beam and tapered undulators.

The performance in this layout was constrained to the long wavelength range (540 nm) because of the relatively low beam energy. The extension of the SPARC beam energy is expected in the next future owing to the installation of C-band accelerating structures replacing the last acceleration section presently installed. The energy upgrade of the SPARC FEL in SASE mode with chirped and tapered configuration should allow delivering short, fully tunable pulses, with comparable pulse energy, in the VUV spectral range well below 200 nm.

The FEL in Seeded Mode

The implementation of a seed source allowed the extension of the SPARC spectral range of more than one order of magnitude with respect to the FEL design operation wavelength. Seeding at SPARC may be implemented in different configurations, which may be optimised

according to the available seed source. The seed may be indeed generated by using the mechanism of high harmonics generation in gas, directly at short wavelengths. In this case, with a beam energy lower than 180 MeV, the amplification of a small seed generated at 160 nm as the 5th harmonic of the Ti sapphire drive laser, has been obtained. In this condition, the FEL resonance condition has been produced with the FEL operating as a single long amplifier with a relatively low undulator strength parameter K=0.85. However, this forced choice has the drawback of reducing the amplifier gain. For this reason a pulse energy of few nJ has been obtained in this condition, but the energy upgrade mentioned in the previous section would ensure a much stronger gain and better performance.
A more efficient way of generating short wavelengths consist in seeding the FEL with a more intense signal at longer wavelengths and use the harmonics generation mechanism. By driving the amplifier with about 10 μJ seed at 400 nm, the spectrum of the first 11 harmonics of the seed has been measured, observing more than 200 nJ at the third harmonic (133 nm). The spectrum is shown in Fig. 2

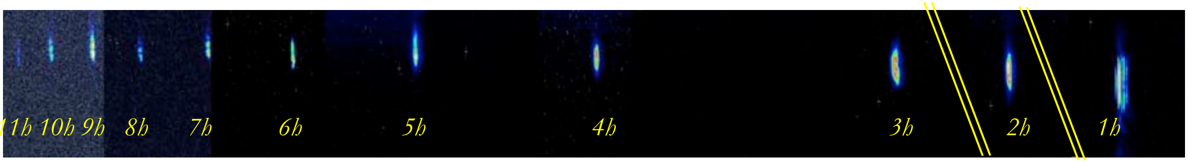

Fig. 2 - Spectrum of the high harmonics generated in the SPARC amplifier seeded at 400 nm.

Even more efficient is the harmonic generation process when implemented in an undulator cascade, where the undulator resonances are set to match the latter resonance of one of the harmonics of the first (See Fig. 3).

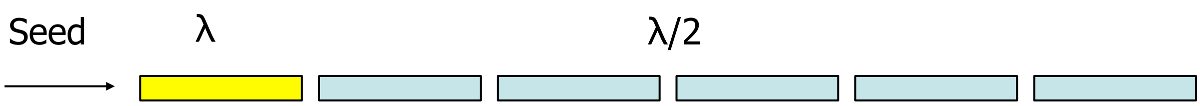

Fig. 3 SPARC undulator in a cascaded configuration.

In the SPARC case this is possible by tuning the gap of the second part of the undulator at the second harmonic of the first one. This experiment has been repeated at different seed wavelengths (400 nm generated in a BBO crystal and 266 nm generated in a gas cell) and with different undulator configurations. Up to 1 μJ has been obtained at 133 nm and about 100 nJ at 66 nm were obtained with a pulse length comparable to that of the seed laser. A summary of the pulse energy obtained in the different modes of operation and at different wavelengths is listed in Table 3

Wavelength	500 nm	200 nm	133 nm	66 nm
Energy/pulse (~ 100 fs)	~100 μJ	~10 μJ	~1 μJ	~100 nJ

Table 3 Energy delivered by SPARC at different wavelengths.

The performance drop observed at short wavelengths is mainly determined by the limited beam energy. For the specific SPARC configuration an increment in the beam energy should be accompanied by a corresponding increment of source performances.

Section C: Project description

C.1 Introduction and overview

The SPARC FEL source built at the Laboratori Nazionali di Frascati of the INFN [4] in collaboration with ENEA and CNR, now in the advanced commissioning phase, may cover a wide energy range from the IR to UV wavelengths for high-resolution spectroscopy studies and possibly Raman imaging.

In the proposed SPARC FEL configuration, the seeding could allow to work with high harmonics in the UV domain (from 400 nm at least down to ~90 nm) at the nominal energy of the electron beam of 155 MeV (or 200 MeV) with a repetition rate up to 10 Hz [5,6]. The radiation spectrum will be slightly tunable in this domain and higher harmonics will be linearly polarized sources of high temporal and spatial coherence emitting pulses as short as 100 fs.

Several experimental set-ups could be considered with the available instrumentations. However, the opportunity to install a high resolution monochromator such as a McPherson 5-meter high-resolution normal-incidence monochromator, which employs two diffraction gratings may open unique opportunities in many fields and in particular in spectroscopy. This available instrument recently released by the SFTC Daresbury Laboratory to the LNF has two interchangeable gratings that may cover the photon energy range 5–35 eV (250 - 35 nm) with a best achievable resolution of 2 meV (0.005 nm). These parameters fits quite well the UV energy range available at SPARC.

C.2 Beamline description and performance modeling

We describe below a possible optical design of a beamline for a dedicated use of the SPARC FEL radiation in the ultraviolet range.

The SPARC FEL radiation is linearly polarized with the polarization plane parallel to the floor. The expected characteristics of the SPARC radiation in saturation (emission of the fundamental) at UV wavelengths are shown in the table below.

Wavelenght (nm)	**Source dimensions (mm rms)**	**Divergence (mrad rms)**	**Energy/pulse (mJ)**	**Photons/pulse**
400	400	0.3	5.5	
266	400	0.2	5	
160	400	0.1	2.5	
114	400	0.06	1.5	
60 (H3 di 180 nm)	400	0.06	$1 \cdot 10^{-3}$	
40 (H3 di 120 nm)	400	0.04	$1 \cdot 10^{-5}$	

Table 4 Characteristics of the SPARC radiation at UV wavelengths.

The characteristics of the beamline are:

- Spectral range of operation:
  100-400 nm (fundamental FEL emission) and
  40-100 nm (FEL harmonics);
- branch with a monochromator for medium / low resolution and a focusing section;
- efficiency of the beamline (without the monochromator) > 10%
- focal spot ~ 200 µm
- time resolution $\Delta t < 200$ fs FWHM @ $\lambda < 120$ nm

The layout of the first section of the beamline is shown in Fig. 4. The planarly-polarized radiation emitted by SPARC will be transported from the ground level of the SPARC FEL source to the LI^2FE laboratory, placed at a level higher than 3 m. The first section of the beamline consists of two flat mirrors working at grazing incidence and in polarization s. The first mirror fold the SPARC radiation upward, while the second makes the beam parallel to the floor. This approach has the advantage of avoiding lowering the floor level of the LI^2FE laboratory to the SPARC floor level and it requires only a vacuum pipe to transport the radiation from the SPARC laboratory area to the LI^2FE building. In addition, this layout also matches the radioprotection requirements easily, since the two mirrors avoid working along the radiation beam line as exiting the undulators. Mirrors will be coated by platinum, a choice supporting a large incidence angle (84.5°) and a reflectivity between 0.85 (@ 40 nm) and 0.95 (@ 400 nm).

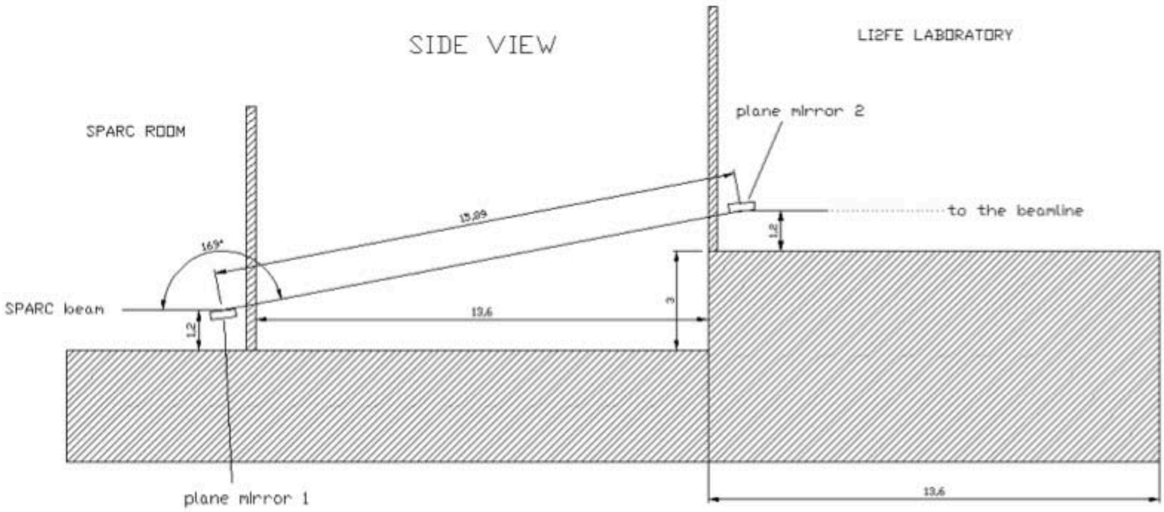

Fig. 4 Side view of the first section of the proposed UV beamline at SPARC.

The beamline with the monochromator and its focusing optics will be installed in the LI^2FE building. The beamline consists of a pre-focusing mirror, a monochromator and a post-focusing mirror that focus the FEL monochromatized beam at the center of the experimental chamber. A simple layout (not to scale) is shown in Fig. 5.

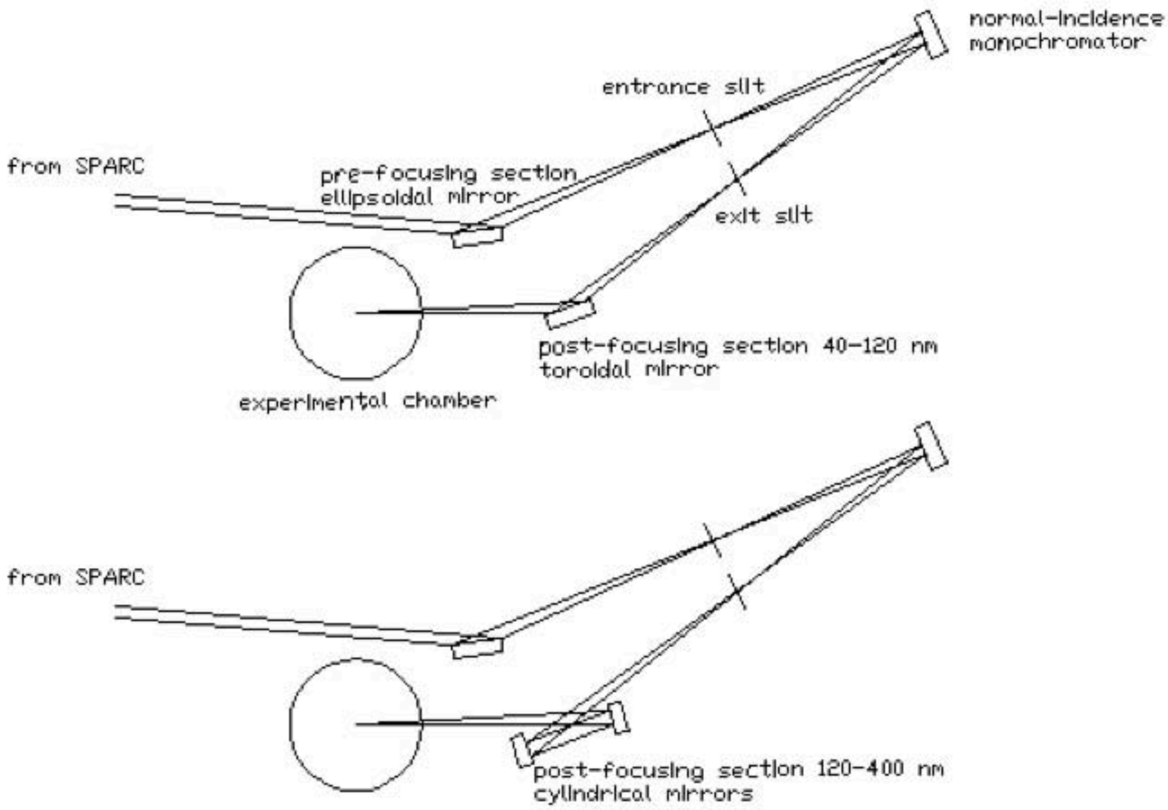

Fig. 5 Side view of the optical layouts of the proposed UV beamline at SPARC for the energy range 40-120 nm (top) and 120-400 nm (bottom).

The pre-focusing mirror is an ellipsoidal mirror illuminated at grazing incidence in p polarization and focuses the FEL radiation at the entrance slit of the monochromator. The mirror performs a demagnification of the FEL source by a factor 10, which is necessary to decrease the size of the source (from 400 μm to 40 μm rms) and to increase the divergence in order to illuminate a sufficiently large area of the diffraction grating.
The monochromator proposed for this beamline is a 1-m Hilger with 18° as collecting angle and two gratings: 600 gr/mm and 1440 gr/mm, available from the CNR-ISM Institute. This monochromator can be used as filter of the FEL radiation, e.g., to cut the fundamental and to select the third harmonic below 100 nm. As alternative, it can be simply used as an optical relay at the zero order.
If the Hilger monochromator will be used at the zero order, the time structure of the FEL pulse will not degrade. On the contrary, if a grating of the monochromator is used, the diffraction from the grating affects the length of the FEL pulse.
The final section of the beamline is the focusing optics that produces the image of the source at the exit slit of the monochromator, inside the experimental chamber. Let us assume working with a unit magnification and mirror focusing arms of 1.5 m, in order to have enough room available to accommodate a relatively large chamber and, in addition, if necessary a differential pumping section.
For the final optics we considered two different layouts in order to maximize the efficiency of the optical system:

1) for wavelengths longer than 115 nm we considered two Al/MgF_2-coated cylindrical mirrors at normal incidence, one for horizontal focusing and one for vertical focusing;

2) for wavelengths shorter than 115 nm we considered a platinum-coated grazing incidence toroidal mirror.

The exit direction of the radiation and the focal position are the same for both the configurations. To ensure this, the post-focusing optics has to be mounted on a motorized translation stage to select from time to time the best configuration.
A detailed top view of the focusing layout of the beamline is shown in Figure 6. The distance from the entrance wall of the laboratory is less than 10 m. In this scheme the focal point coinciding with the experimental chamber is set at more than 5 m from the wall of the LI^{2}FE laboratory, so that it will be possible to accommodate also the high-resolution McPherson monochromator.

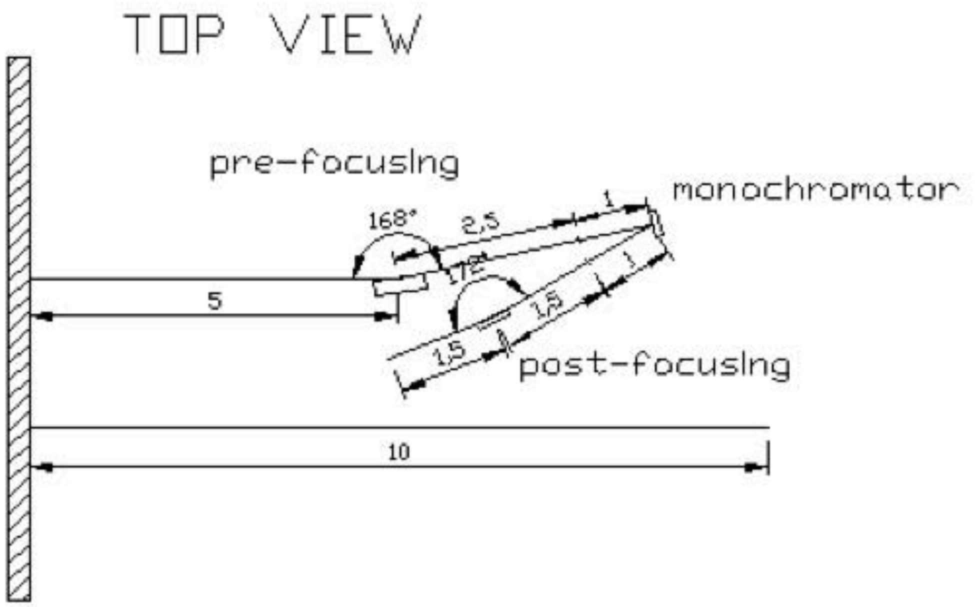

Fig. 6 Top view of the pre- and post-focusing layout of the UV beamline at SPARC.

The expected characteristics of the SPARC source in saturation are summarized in table 5. According to the parameters of the SPARC FEL source, mirrors have been designed to collect ~ 80% of the flux at 400 nm with the largest beam divergence. This is a reasonable compromise avoiding the use of long mirrors (very expensive and with poor surface figures) and minimizes flux losses at longer wavelengths where, however, the SPARC source is not optimized. The main parameters of the beamline are summarized in table 6.

Lunghezza d'onda (nm)	Dimensioni sorgente (m rms)	Divergenza (mrad rms)
400	400	0.3
266	400	0.2
160	400	0.1
114	400	0.06
60 (H3 di 180 nm)	400	0.06
40 (H3 di 120 nm)	400	0.04

Table 5 Characteristics of the UV SPARC source in saturation.

Flat mirrors 1 and 2	
Incidence angle	84.5°
Useful area	45 mm × 10 mm (mirror 1) 200 mm × 40 mm (mirror 2)
Coating	platino
Polarization	*s*
Ellipsoidal mirror	
Entrance arm lenght	25 m
Exit arm lenght	2.5 m
Demagnification	10
Incidence angle	84°
Useful area	250 mm × 30 mm
Coating	Pt
Polarization	*p*
Monochromator	
Grating	600 gr/mm (grating 1) 1440 gr/mm (grating 2)
Collection angle	18°
Focal length	1 m
Plate factor	1.67 nm/mm (grating 1) 0.69 nm/mm (grating 2)
Toroidal mirror	Focalizzazione i.r. in camera sperimentale
Spectral range	40-120 nm
Entrance/Exit arm length	1.5 m
Magnification	1
Incidence angle	86°
Bending radius	14330 mm (tangential) × 70 mm
Useful area	70 mm × 10 mm
Coating	Pt
Polarization	*p*
Focal spot	80 mm FWHM
Cylindrical mirror	Focalizzazione i.n. in camera sperimentale
Spectral range	120-400 nm
Entrance/Exit arm length	≈1 m
Magnification	1
Incidence angle	< 10°
Horizontal radius	1195 mm
Vertical radius	1090 mm
Useful area	20 mm × 20 mm
Coating	Al + MgF
Focal spot	80 mm FWHM

Table 6 The main parameters of the UV beamline.

Considering a demagnification of 10, the size of the entrance and exit slits to transmit all the radiation is 200 µm. Ray-tracing simulations show that the focal spot is ~80 µm rms for both beamline configurations by using such slits. The pulse lengthening due to the diffraction by the grating depends on the beam divergence inside the monochromator. Table 7 shows the pulse length as a function of wavelength.

The FEL resolution has been calculated as the Fourier limit as $\lambda/\Delta\lambda_{FWHM}$ and if the pulse has no flat phase, the resolution decreases. The resolution of the monochromator has been calculated with a slit of 200 µm.

	FEL SEEDED	600 gr/mm grating		1440 gr/mm grating	
wave (nm)	FWHM resolution	resolution	rms DT (ps)	resolution	FWHM DT (ps)
400	170	1200	1.70	2880	4.07
266	256	800	0.75	1920	1.81
160	425	480	0.23	1150	0.54
114	597	340	0.10	820	0.23
60	1134	180	0.05	430	0.12
40	1701	120	0.02	290	0.05

Table 7 Pulse characteristics as a function of the wavelength and grating parameters.

At long wavelengths (λ > 160 nm) the available monochromator resolution is always higher than the best resolution achievable with the FEL radiation. However, time lengthening is much longer than the FEL pulse ($\Delta\tau_{FWHM} \leq$ 100 fs). If we want to avoid selecting a portion of the FEL spectrum (with an unavoidable consequent flux loss) it is preferable to work with the monochromator as a optical relay optical with no effect on the pulse length.

At short wavelengths, where we have to use the harmonics of the fundamental (λ <100 nm), the use of the monochromator is mandatory to transmit the wavelengths of interest rejecting the fundamental. In this case, the lengthening of the pulse is always contained within 200 fs FWHM and the resolution of the monochromator is enough to transmit the full bandwidth of the FEL emission and due to the decrease of the FEL bandwidth without no further reduction of the photon flux. If we need both a short response time and a high photon flux, below 160 nm, the monochromator has to be used as it is.

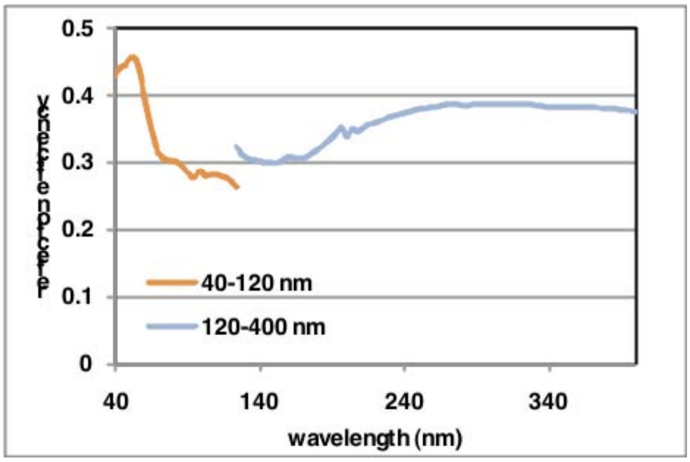

Fig. 7 Estimated efficiency of the optical systems of the beamline in the UV range.

The efficiency of the optical system (neglecting the efficiency of the monochromator) has been calculated taking into account the reflectivity of the various mirrors of the optical layouts (see Fig. 7). The main contribution to the efficiency decrease is given by the ellipsoidal focusing mirror in p polarization which can not be used at extreme grazing incidence. Indeed, in the latter geometry, we would need a very long mirror to collect radiation at longer wavelengths.

Regarding mirror damage, the only critical surfaces are the two cylindrical mirrors working at normal incidence. However, the illuminated area on the cylindrical mirrors is about 0.25 cm^2 at half maximum so that with a FEL pulse of ~ 6 μJ, the expected energy delivered by SPARC at 400 nm, the power load at the mirror surfaces is well below the threshold of the damage of the coating, which is of the order of 50 mJ/cm^2.

Section D: The scientific case

Using a high-resolution monochromator, different experimental opportunities are open to spectroscopic investigations of the structure of small and large clusters, which is a topical issue under continuous development at 3rd generation synchrotron facilities. Such studies on free clusters and thin solid films obtained from their deposition aim at following the evolution of the properties of the matter starting from a single isolated particle toward surface and bulk condensed phase, passing through steps of atomic and molecular aggregates of increasing complexity [7-9]. Given the extremely low number of target particles in cluster experiments, great advances are expected at 4th generation synchrotron radiation sources such as FELs like SPARC.

Although much experimental effort has been addressed towards studies of rare gas and molecular clusters, studies on aggregates of elements with high vaporization temperatures are still at their infancy. At the Gas Phase beamline (Elettra, Trieste) a test project produced encouraging results on studies of free and deposited nano-carbon and transition metal (Ti and Ti-oxides) [10-12].

Pulsed-Laser Deposition (PLD) is a simple and versatile technique that provides an alternative approach to produce samples of refractory materials. A typical sample is transferred from a laser-ablated target to a substrate where it is deposited. The reactivity of the ejected species mainly determines the properties of the final deposit. Previous work done at CNR-IMIP has investigated the ablation mechanisms in a range of materials and established the conditions for ablation [13] that favor the formation of free clusters of varied chemical nature [14].

The main goal of the proposed studies is to expand them implementing VUV resonant Raman techniques. Indeed, Raman spectroscopy is one of the most popular methods to characterize nano-structured systems. The ability of the VUV-FEL to shift the wavelength of the scattered light from the visible into the deep UV will allow to probe new electronic transitions well within the 7-10 eV range for classes of cluster materials such as nano-carbons and potential gap dielectrics from metal oxides.

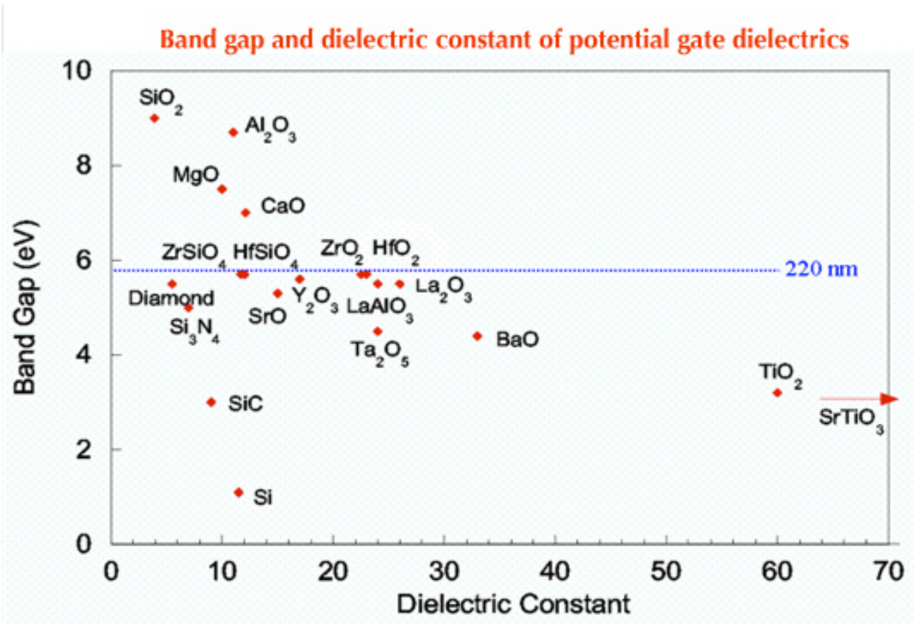

Fig. 8 Correlation map between band gap and dielectric constant in many insulators and semiconductor materials. The dotted line points out the gap value of 220 nm (~5.64 eV).

The possibility of performing Raman spectroscopy on the isolated building blocks of a nano-structured film is of paramount importance. Moreover, experimental data on wide band-gap materials would also contribute to the knowledge of their electronic structure and of the mechanisms of the relaxation of electronic excitations in many fundamental compounds as addressed in Figure 8. Future developments exploiting also variable polarization of the exciting radiation and/or time resolution in the detection of the scattered light would allow for the separation of different emission processes in wide band-gap materials of great interest for many technological applications.

A high-resolution monochromator could be also considered for circular dichroism and resonance Raman microscopy experiments both having the potential for functional imaging. Both methods require a brilliant radiation source between 140 and 220 nm, a wavelength region not covered adequately by conventional lasers. Many applications will be possible either yielding structural details on materials or biological systems such as proteins, carbohydrates, and nucleic acids, or information on time-dependent mechanisms.

We are particularly interested in the possibility of performing Raman chemical imaging, a powerful technique for routine analysis of the chemical architecture of materials that could be possible with the SPARC source. Combining digital imaging methods with the high performance Raman spectroscopic source, the molecular composition could be efficiently achieved and a useful approach for understanding the relationship between a material's molecular architecture and its function will be available. As an example, time-resolved resonance Raman microscopy could allow real-time investigation of the chemistry of sub-cellular domains.

Raman chemical imaging is not limited to microscopic analysis and should be performed also on large samples if the source will have a sufficient optical power to maintain high-power densities across a large sample area. The SPARC VUV FEL source with a pulse energy of the order of 10 μJ or more promises to be suitable for wide-field Raman chemical imaging of large samples providing the necessary peak power or energy per single pulse.

In addition, with respect to time-resolved studies, sub-ps high-resolution spectroscopy can be of great interest in a wide range of applications concerning opto-materials and photonics devices, optical system testing and astrophysical plasmas.

Charge lifetime and transport phenomena can be assessed by ultra-fast and monochromatic beams on materials and devices for electro-optical or photonics applications. Specific energy levels can be excited and their fluorescence decays studied with extremely high time resolution in order to infer the recombination or trapping mechanisms. It will be also very interesting to characterize interfaces between multilayered materials, where surface states are abundant and very effective on limiting the carrier behavior and lifetime. When combined with high-resolution spectroscopy, this technique can be advantageous to investigate systems where many states overlap, such as wide band-gap materials that can be pointed out and studied in great detail.

SPARC is also a perfect source for two photon photoemission (2PPE) experiments, a technique that matches the advantages of direct and inverse photoemission. In the time-resolved pump (external laser) and probe (FEL) configuration, it provides a powerful tool for the investigations of excited states, in terms of the extension radius and lifetime of excitons, polarons, spin-charge-orbital ordering and the like [15]. Such states can be strongly modified in confined structures or in hybrid organic-inorganic hetero-junctions of organic solar cells [16] and in modulation doped semiconductor heterostructures of metal-semiconductor interfaces, and spintronics devices such as spin valves or diluted magnetic semiconductors. The use of the SPARC FEL sources with tunable energy may be crucial to enhance the resonant photoemission mechanism from more or less shallow levels beyond the limitation given by a low frequency laser or low intensity plasma/discharge UV lamps, providing a precise targeting of excited state by the mapping of their Fermi surface.

Finally the photon energy range of the SPARC FEL will give access also to the photoionization thresholds of many atmospheric constituents from troposphere, up to ionosphere, and it's pulsed time structure makes it an ideal source to study not only spectroscopy, but also dynamics induced by light in such complex media with state of the art mass spectrometric and electron spectrometry techniques. The same applies to biosphere constituents, where the possibility of changing polarization of the FEL light from linear to circular means it will be possible to add important information to investigation such as correlating chirality and natural dichroism in biotic media to the electronic structure of its basic constituents.

The high brightness of this FEL source will allow the first direct investigation of systems with low density and spectroscopic studies of exotic species. The laser photo-dissociation and, more generally, the interaction of a laser with an appropriate precursor, are often the most selective way to produce reactive radicals and metastable species of interest to the chemistry of the atmosphere or the study of combustion phenomena. The interaction of a material with laser radiation may also lead to the vaporization of chemicals that would otherwise produced only in extreme conditions of high temperature.

A UV monochromatic beamline together with photoemission techniques would allow the study of species of interest in the physics of the upper atmosphere and in combustion. The electronic structure of these species have been extensively studied in the range of optical, but is not very well known in the region of photoionization due to the lack of high intensity sources at wavelengths below 180 nm.

Similarly, the photo-dissociation laser of compounds with metal centers or the laser ablation technique allow releasing metals such as tungsten or vanadium in the gas phase without having to reach the high temperatures of the conventional effusive ovens. At the same time the coupling of laser techniques with supersonic beam technologies make possible the study of aggregates (clusters) of these species, isolated in the gas phase and with a sufficient density for studies with photo-ionization and photoemission techniques.

For the above examples, the emphasis has been given on the study of the electronic properties of the species produced by conventional high-intensity laser sources which can be now studied with the FEL radiation. However, we may underline here that the availability of SPARC, a high flux source at wavelengths shorter than 150 nm would also allow testing the reverse scheme, i.e., use the conventional laser radiation to investigate exotic species generated in a controlled manner by a FEL beam. The field could be then expanded investigating species produced in specific processes characteristic of the upper atmosphere, e.g., above or in contact with the atmospheric ozone layer, such as the photo-dissociation of water into hydrogen and atomic oxygen or the decomposition of carbonyl compounds in the metastable carbon monoxide, hydrogen atoms and hydrocarbon radicals.

Acknowledgements

A sincere thank goes to Daresbury Laboratory who approved the transfer of the high-resolution monochromator that served hundreds of users during the synchrotron radiation operation at SRS until the shut down of the facility.

In particular, we sincerely acknowledge Ray L. Jones and the SFTC Daresbury staff that support and assist the disassembling and transfer of the McPherson monochromator. Thanks are also due to the LNF staff for the operation at Daresbury and here at Frascati before, during and after the transfer of the monochromator.

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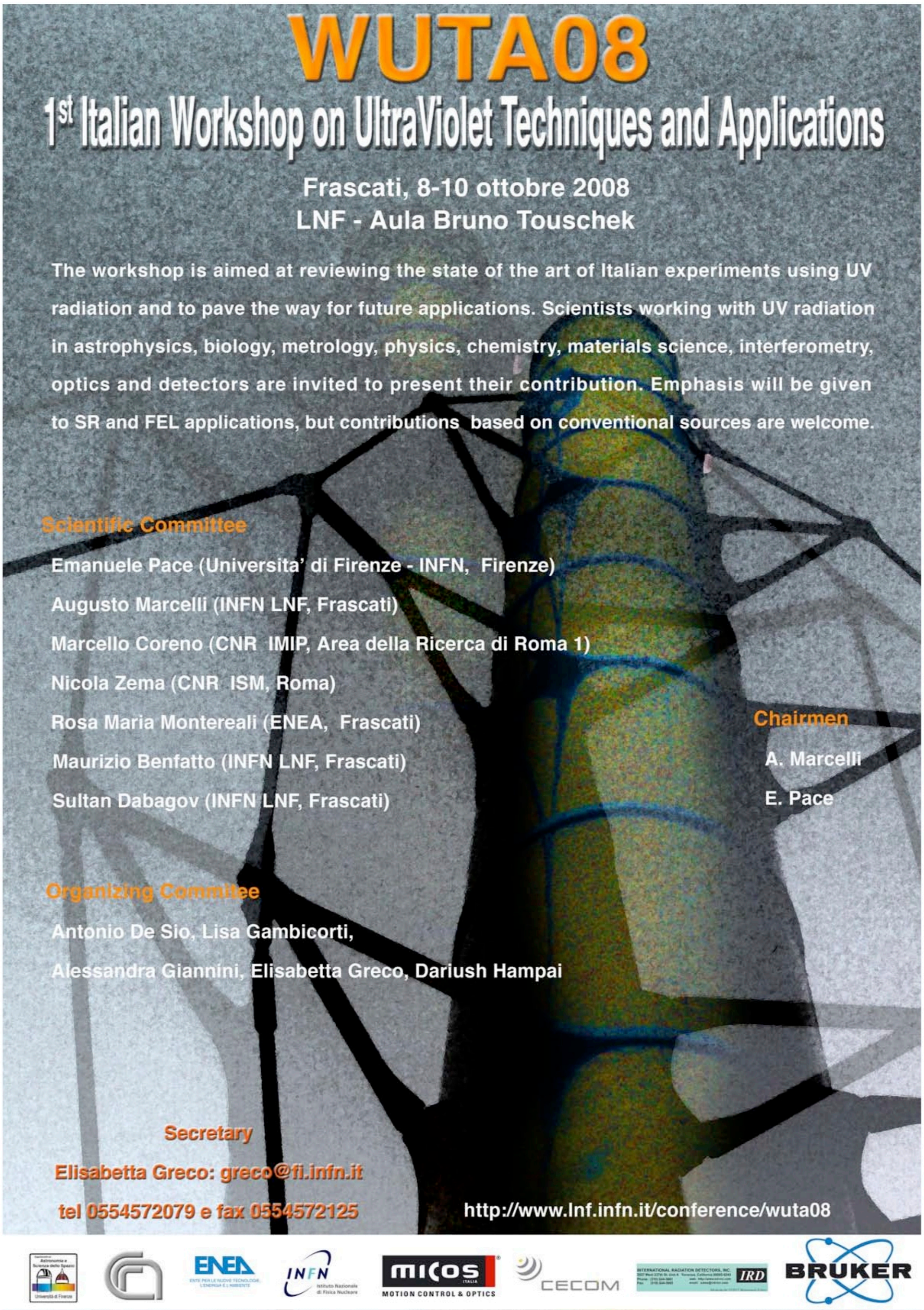
Appendix – Scientific Workshops (WUTA09)



http://www.lnf.infn.it/conference/wuta08/

WEDNESDAY 8 OCTOBER

11.00-13.00 **Registration**

UV Foreword *(Chairman E. Pace & A. Marcelli)*

14.30 *Welcome*

14.45 Invited talk - *VUV metrology programs supporting space research*
Robert E. Vest (NIST, USA)

15.30 Invited talk – *Entanglement in Space-Time: "Suddenly this overview, big questions, small questions"*
Uwe Becker (Fritz-Haber-Institut, Berlin)

16.15 *Coffee break*

16.45 Invited talk - *Inelastic UV Scattering Experiments and Perspectives*
Claudio Masciovecchio (Sincrotrone Trieste)

17.30 Invited talk – *VUV photoemission spectroscopy*
Kevin Prince (Sincrotrone Trieste)

18.30 *Bus to the Hotel*

THURSDAY 9 OCTOBER

Astrophysics *(Chairman E. Pace)*

9.00 Invited talk – *UV astrophysics: hot topics and demands for future instrumentation*
Isabella Pagano (INAF, Osservatorio Astrofisico di Catania)

9.45 *Far Ultraviolet Studies of the Missing Baryons in and around our Galaxy: Current Evidence and Perspectives*
Fabrizio Nicastro (INAF, Osservatorio Astronomico di Roma)

10.05 *Astrophysical Ultraviolet Spectroscopy: the Laboratories on Earth and in Heaven"*
Steve Shore (Università di Pisa)

10.30 *Coffee break*

UV instrumentations and detectors *(Chairman K. Prince)*

11.00 *Status of the BAdElPh project at Elettra*
Paolo Vilmercati (Università di Trieste e Sincrotrone Trieste)

11.20 *Study of UV absorption and photoelectron emission in RPC (resistive plate counters) detectors with an UV source*
Carlo Gustavino (INFN – LNGS)

11.40 *High performance imaging detector for extreme ultraviolet radiation and soft X-rays*
Francesca Bonfigli (ENEA, Frascati)

12.00 *XUV diamond detectors*
Antonio Desio (DASS – Università di Firenze)

12.20 *CVD single crystal diamond UV photodetectors for UV plasma diagnostic at JET tokamak*
Claudio Verona (Università di Roma Tor Vergata)

12.40 *High Performance UV Beam-Profile Meters Based on CVD-Diamond*
Marco Girolami (Università di Roma Tre)

13.00 *Lunch*

Exobiology *(Chairman S. Shore)*

15.00 *Evading quantum de-coherence in living matter by Feshbach resonance*
Antonio Bianconi (Università La Sapienza, Roma)

15.20 *UVB-induced effects on Jurkat cells: a filter provided by vegetable mixture*
Lucia Di Giambattista Lattanzi (CISB - Università La Sapienza, Roma)

15.40 *Prebiotic Chemistry and the Origin of Life. The possible role of UV radiation*
Claudia Crestini (Università di Roma Tor Vergata)

16.00 *Chemical evolution in space driven by UV and ion irradiation*
John Brucato (INAF – Osservatorio Astrofisico di Arcetri, Firenze)

16.30 *Coffee break*

Astronomical UV instrumentation *(Chairman R.E. Vest)*

16.50 *Technologies, materials and coatings for high precision astronomical optics*
Mauro Ghigo (INAF, Osservatorio Astronomico di Brera)

17.10 *Liquid Argon XUV scintillation light detection for direct Dark Matter search: the WArP Experiment*
Francesco di Pompeo (INFN - LNGS)

17.30 *General discussion*

18:00 *Short visit to the DAFNE complex and the SPARC accelerator*

FRIDAY 10 OCTOBER

Emerging UV sources: FELs *(Chairman L. Avaldi)*

9.00 Invited talk - *The SPARC FEL and its opportunities at UV wavelengths*
Luigi Palumbo (Università La Sapienza & INFN - LNF)

9.45 *Photoionization in the VUV: from synchrotron to coherent harmonic radiation at EUPhOS*
Marcello Coreno (CNR-IMIP)

10.05 *Probing free metallic and carbon clusters with high energy photons*
Paolo Piseri (CIMAINA e Università di Milano)

10.25 *Coffee break*

10.50 *Seeding the SPARC FEL amplifier*
Luca Giannessi (ENEA, Frascati)

11.10 *Molecular recognition in complexes of fluorinated chiral aromatic molecules with water, amines and alcohols: a mass resolved R2PI spectroscopic study.*
Flaminia Rondino (CNR-IMIP & Università La Sapienza, Roma)

11.30 *Experiences at FLASH and plans for SPARC*
Patrick O'Keeffe (CNR-IMIP, Roma)

11.50 *High-resolution rotovibrational autoionisation of H_2/D_2 involving transitions beyond the Born-Oppenheimer approximation*
Michele R.F. Siggel-King (CCLRC Daresbury Laboratory, UK)

12.10 *General discussion*

13.00 *Concluding remarks*