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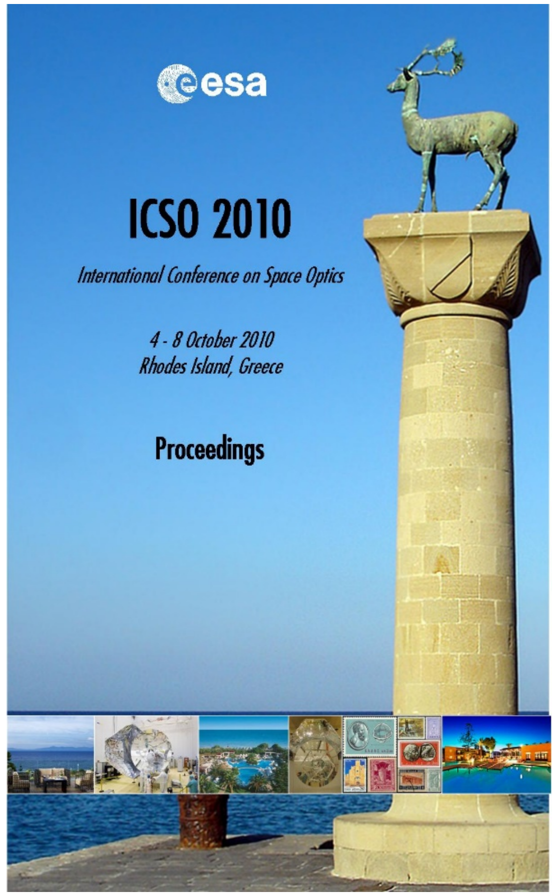

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SOURCE, A VUV-UV SYNCHROTRON RADIATION BEAMLINE FOR SPACE OPTICS TESTS AT THE DAΦNE-LIGHT INFN-LNF

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ABSTRACT

DAΦNE-Light is the Synchrotron Radiation Facility at the INFN-Frascati National Laboratory (Rome, Italy). The synchrotron radiation (SR) beam from a wiggler installed on the DAΦNE storage ring is split by a grazing incidence Au-coated mirror (θ_i=40 mrad, cut-off energy ~ 800 eV), in order to provide the X-ray and UV beam lines. The reflected UV radiation travels through the UV beamline and ends in SOURCE, a three-channel experimental set up. The first light path is a near UV/VIS experimental apparatus, providing intense monochromatic radiation (~ 10^{11} ph/s in a 2x7 mm spot size) in the 200-650 nm spectral range. The second light path is the VUV channel operating in the 120-400 nm. The third channel is a wide-band UV/VIS radiation source. The beam line has been partially operating since 2009 using the intense SR emission of DAΦNE - a 0.51 GeV storage ring with a routinely circulating electron current higher than 1 A - in parasitic and dedicated-time mode. This very high current produces the higher UV SR photon flux in the world. SOURCE is open to users applying UV irradiation to biological materials, rocks or meteorites, material science, photo-biology, detector testing and development, medical applications, calibration of space instrumentation. SOURCE is devoted to experiments requiring very intense radiation beams or to calibrate large space optical systems in the VIS/UV/VUV, owing to the large cleanroom available at the end of the beam line.

INTRODUCTION

The ultraviolet (UV) and visible radiation are of great interest for astrophysical or Earth observations from space. Also space- or ground-based experiments investigating the nature and the properties of cosmic rays make use of the Cherenkov and fluorescence UV radiation emission. Therefore, the availability of calibration and testing facilities is crucial as optical ground support equipment during the AIV phase and the on-ground calibration of space mission payloads. The synchrotron radiation (SR) beam lines available at the *DAΦNE-Light* laboratories of the National Institute for Nuclear Physics (INFN) in Frascati, close to Rome (Italy), appear to be an appealing radiation source to carry out electro-optical and functional tests of large optical systems and focal plane detectors. In fact, SR offers several advantages over traditional sources: its spectrum is a continuum covering a very broad energy range and its flux is known at each energy; SR is pulsed radiation having very short pulses (a few ns), that is ideal to assess the detector response time; the pulse rate is very high so, single pulse – or pulse trains – or integrated measurements are possible.
These premises stimulated the proposal for a VUV-VIS test facility for even large (up to 4-m diameter) space optical systems. Nevertheless, such a UV/VIS SR source will be open to scientists working in other research fields. This facility is presently under construction, but partially available for experiments using near-UV and visible SR, and it will be completed at the end of 2010.

THE SOURCE BEAM LINE

DAΦNE (Double Annular Φ Factory for Nice Experiments) is a positron-electron collider for fundamental physics experiments (Fig.1) available at the Frascati National Laboratories of the INFN. The SR beam from one of the wigglers installed on the DAΦNE storage ring is collected and split by a grazing-incidence Au-coated mirror (θ_i=40 mrad, cut-off energy ~ 800 eV), in order to provide the X-ray and UV beam lines [1]. The main target of the SOURCE (Synchrotron Optical & Ultraviolet Radiation for Calibration Experiments) beam line is calibration and test of space optical instrumentation at UV and visible wavelengths (120-650 nm). The extreme versatility of the beam line setup is also open to experiments in many interdisciplinary fields of research. In particular, experiments requiring very intense monochromatic beams, precise photometric calibrations, material irradiation (degradation, aging, UV resistance, etc.) for biological materials, material science, photo-biology, rocks and meteorites, detector testing and development, medical applications, polarimetric measurements, can found a unique opportunity because of the highest UV/VIS SR flux in the world.

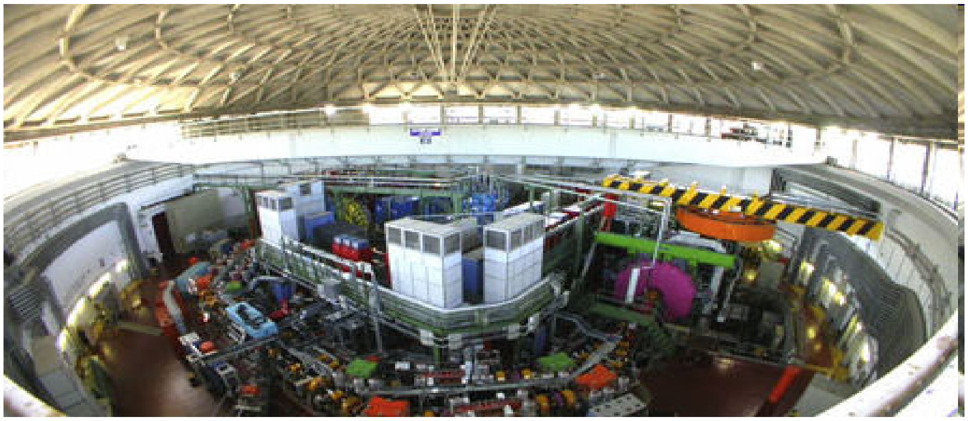

Fig. 1. DAΦNE-Light is the SR facility at the INFN-Frascati National Laboratories (Rome, Italy). This picture shows the DAΦNE positron-electron storage ring.

As mentioned, SOURCE makes use of the intense SR emission from the DAΦNE electron storage ring. The distinguishing feature of the DAΦNE collider (a storage ring of 0.51 GeV electrons) is the very high electron current whose values range from 1A to 2A. Owing to this high current, SOURCE is unique for its very high UV/VIS SR flux over a wide energy range. The beam line can be operated both in parasitic mode (during particle physics experiments) and in dedicated-time mode. During dedicated time, the number of electron bunches, the current level and the bunch distribution can be modified to satisfy the experimental requirements.

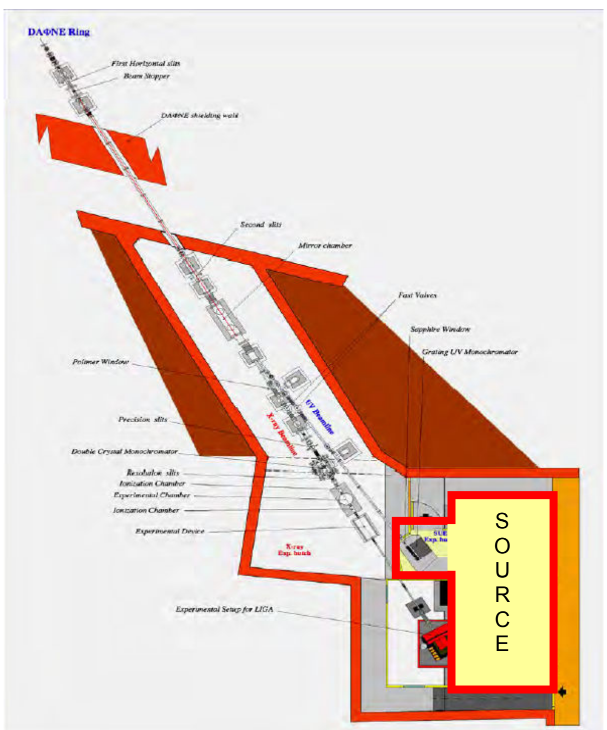

Fig. 2. The SR beam from a wiggler installed on the DAFNE storage ring is split by a grazing incidence Au-coated mirror, in order to provide the X-ray (the straight beam line) and UV beam lines. The SOURCE area shows the location of the clean room including the three experimental radiation channels.

The optical layout of the whole apparatus has been designed in collaboration with the CNR-National Institute of Optics at Firenze. Fig.2 shows the SR beam line layout. The yellow SOURCE area at the bottom right in Fig.2 shows the location of the 1000-class clean room including the three experimental radiation channels. The first light path is a UV/VIS experimental apparatus, providing intense monochromatic radiation (~ 10^{11} ph/s in a 2x7 mm spot size) in the 200-650 nm spectral range (see Fig 3). The second light path is the VUV channel operating in the 120-400 nm. The third channel gives large-band UV/VIS radiation. The available overall spectral range is limited at lower wavelengths by the MgF_2 window closing the vacuum beam line and by the grating efficiency at longer wavelengths. The absolute radiation intensity is known owing to the linear relationship between the electron current in the storage ring and the SR emission intensity. This relationship can be calibrated at each wavelength with a NIST calibrated silicon photodiode. The output current signal is amplified and converted into a voltage signal by a Keithley 427 Current Amplifier (maximum gain 10^9 V/A) and then acquired by a computerized Analog to Digital Converter (two results of calibration measurements are reported in Fig.3, where the spectral intensity of the beam exiting the monochromator has been plotted versus the wavelength [2].

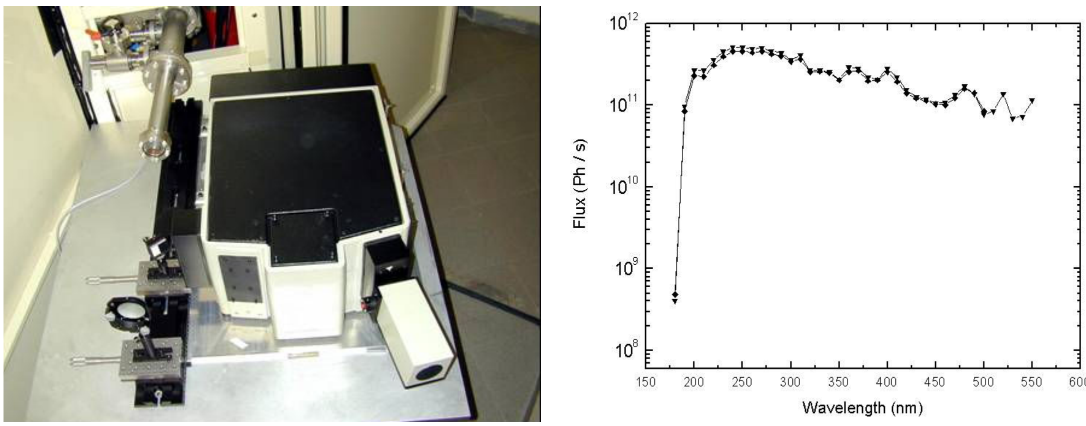

Fig. 3. The Jobin-Yvon Czerny-Turner optical monochromator (left panel) gives monochromatic radiation to the VIS/UV channel. Intensity spectra of the radiation exiting the monochromator (right panel). The intensity values are normalized to the 1 A electron current circulating into DAΦNE.

The optical MgF_2 window sealing the UHV beam line is coupled to a polarimetry chamber and then to a high vacuum (HV) chamber containing a toroidal mirror (Fig.4) and a planar folding mirror. This couple of mirrors focuses the outgoing radiation from the beam line into the experimental apparatus inside the clean room and compensates the astigmatism aberration of the beam. Inside the clean room, the radiation is directly focused at the entrance slit of a VUV monochromator that is coupled to an HV experimental chamber (Fig.4) or it can be folded at the entrance slit of the VIS/UV monochromator (Fig.3) or at the entrance aperture of a UV-grade fiber optics feeding the UV-VIS large-band channel.

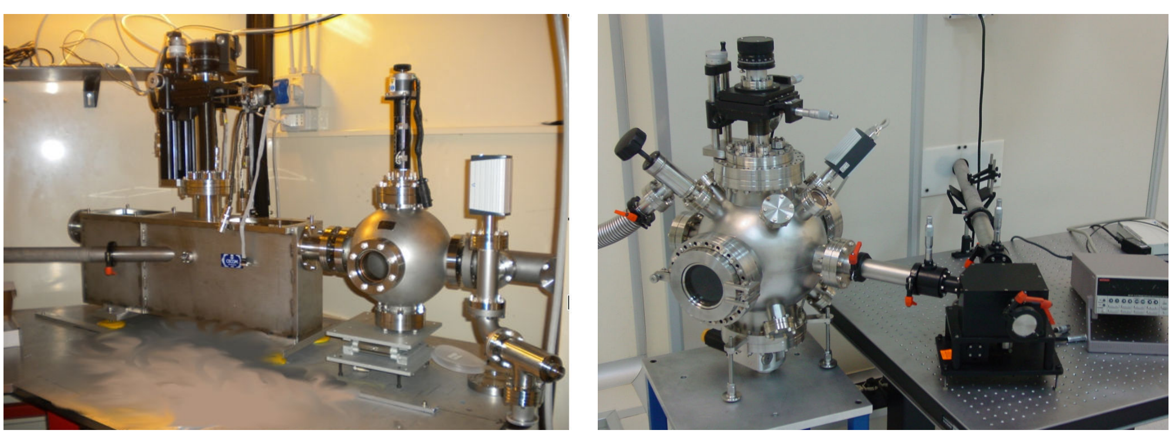

Fig. 4. The beam line entrance, the polarimeter chamber and the HV chamber containing the mirrors (left picture) that focus the radiation inside the clean room where the three channels are arranged. The VUV monochromator coupled to the HV experimental chamber at the end of the line (right picture).

The polarimetry chamber contains a planar mirror folding the incoming radiation up to a polarimetric channel for linear polarimetry analysis. This channel is currently under design and its completion is scheduled for 2011. The beam line is designed to operate continuously. As already mentioned, it operates in parasitic and in dedicated-time mode in order to use SR when available. Conventional power lamps emitting radiation in the whole spectral range of interest are also available to feed the channels during the DAFNE shut-down periods.

CONCLUSION

DAΦNE-Light is the SR facility at the INFN-Frascati National Laboratories (Rome, Italy). The SOURCE beam line uses the intense UV and visible SR emission of DAΦNE, the storage ring at the Frascati National Laboratories, in parasitic and dedicated-time mode. It is composed by 3 main light channels and it allows measurements in a very wide spectral range from 120 nm up to 650 nm (2-10 eV). This facility is available to users for several scientific investigations making use of the VIS-UV-VUV radiation, as for example characterization of optical instrumentation for ground-based or space experiments, calibration of detectors, photonic devices, material science as nano-carbons, wide band gap materials, thin films and coatings. Moreover, UV irradiation experiments to study the degradation, aging and resistance of materials or in the field of photobiology, photochemistry, and mutations of organic and genetic materials to support the astro-biological research for the origin of life or for medical application can be carried out.

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