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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

First experimental tests at the new synchrotron radiation facility ELETTRA in Trieste

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Only three weeks after the beginning of commissioning, the new ultrabright synchrotron source ELETTRA was able to deliver the first experimental test data. We briefly discuss these test experiments, which produced a series of photoelectron micrographs of different specimens. This success concludes, to the best of our knowledge, the most rapid first phase of commissioning ever of a synchrotron radiation source.

In the course of 1993, three ultrabright synchrotron sources of soft X-rays were put in operation: the Advanced Light Source (ALS) in Berkeley, the Synchrotron Radiation Research Center in Taiwan, and ELETTRA in Trieste, Italy. Considering the difficulties in commissioning the previous (second) generation of sources, one could have expected long commissioning periods and perhaps unforeseen technical difficulties. On the contrary, all of the new facilities went very rapidly through their first commissioning phase. This is excellent news for the most sophisticated and demanding experiments that depend on them and on their reliability.

We present a brief report on the first commissioning phase of ELETTRA, whose rapidity was quite spectacular, leading in three weeks to the first set of test experimental data. The main steps of this process were the following:

October 5, 1993: the commissioning of the source initiates three years after the beginning of the buildings construction. In less than two shifts of operation, the injection system is set up to obtain the first turn of the electron beam and to increase the number of turns to 2000.

October 6: the radiofrequency system is turned on and *the first beam is stored in ELETTRA.*

October 7–17: the intensity of the circulating current is increased to 216 mA.

October 25: the first experimental tests begin.

October 28: the tests are successfully concluded.

We can see, therefore, that only a few days of commissioning were necessary to obtain the first stored beam, and only three weeks to obtain the first data.

In order to put this performance in perspective, one must consider the advanced characteristics of ELETTRA. A detailed account of ELETTRA's beam parameters and performance during the commissioning period will appear elsewhere [1]. We note here that ELETTRA, whose main characteristic are listed in Table 1, is the brightest source of soft X-rays in the world together with the ALS. Its maximum design brilliance from insertion devices is 8×10^{18} photons/s/mm^2/mrad^2 for a 0.1% bandwidth.

This high brilliance is the results of two factors: low emittance and the use of insertion devices such as wigglers and undulators. Two of the ELETTRA's undulators are already installed and have been operated.

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† Deceased: this work is respectfully dedicated to his memory.

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Table 1
ELETTRA's parameters – summary

Circumference [m]	259.2	
Number of achromats	12	
Number of bending magnets	24	
Bending radius [m]	5.5	
Beam current, multibunch mode [mA]	400	
Beam energy [GeV]	2	1.5
Critical energy [keV]	3.2	1.4
Natural emittance [π m rad]	7.1×10^{-9}	4.0×10^{-9}
Maximum flux from bending magnets at 400 mA [photons/s/0.1%bw/mrad]	1.8×10^{13}	1.4×10^{13}
Maximum flux from insertion devices at 400 mA [photons/s/0.1%bw/mrad]	$5\ \times10^{15}$	$4\ \times10^{15}$
Maximum brilliance from bending magnets at 400 mA [photons/s/0.1%bw/mm^2/mrad^2]	$5\ \times10^{14}$	$5\ \times10^{14}$
Maximum brilliance from insertion devices at 400 mA [photons/s/0.1%bw/mm^2/mrad^2]	$6\ \times10^{18}$	$8\ \times10^{18}$

The good performances as an accelerator notwithstanding, a synchrotron source's success in experiments depends on its reliability. It is certainly too early to make definite statements about ELETTRA's reliability. But there is very encouraging news from the most practical and stringent test: its early use to produce experimental data.

The technique for these test experiments were photoemission microscopy, which consists of using the synchrotron radiation photons to excite photoelectrons, and then of creating microimages by means of an electron-optic system. The philosophy of this technique is discussed in detail in Ref. [2]. The first experiments on ELETTRA are certainly far from the best possible performances, and were performed on systems that have already been extensively studied with similar experiments. The data, therefore, are merely used to assess the overall working conditions of ELETTRA in its first phase of commissioning. In this respect, the tests were entirely successful.

Fig. 1 shows the very first photoelectron microimage produced by ELETTRA: the photoelectron micrograph of

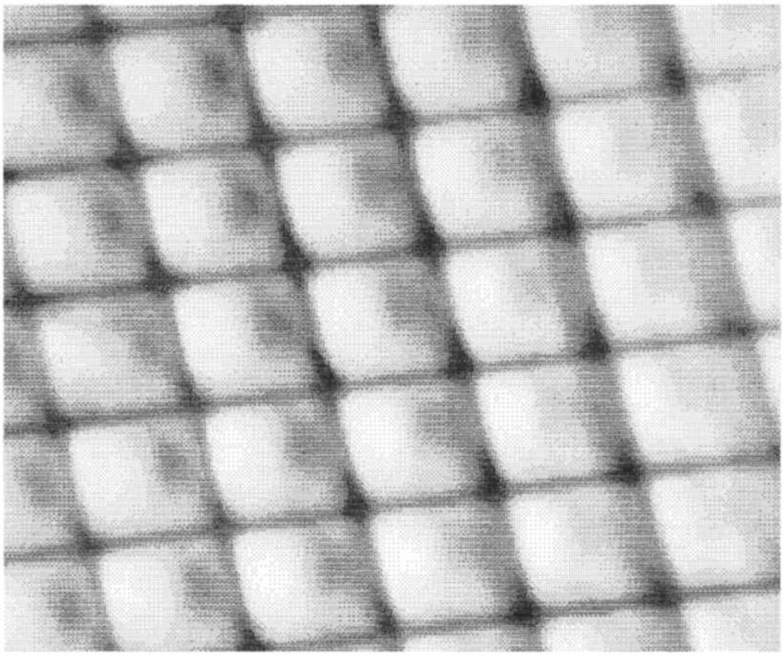

Fig. 1. The first experimental result obtained on ELETTRA: X-ray photoelectron micrograph of a metal mesh, whose step is of 20 μm.

a metallic mesh with 20 μm steps. The lateral resolution (without optimization) is of the order of 1 μm. The schematic experimental configuration was the following: bending-magnet radiation was collected from one of the front ends reserved for undulators, the entire experimental system being surrounded by a shielding hutch to guarantee safe operation. The synchrotron-photon excited photoelectrons were subsequently processed by a PEEM [3] (photoelectron emission microscope) electron optics. The fluorescent screen of the PEEM system created real-time video images that were recorded on tape and subsequently computer-captured.

A very large number of video images were obtained during the first test runs. Mesh images like those of Fig. 1 were primarily used for calibration and general instrumentation tests. Fig. 2 shows instead an example of a microimage from a biological specimen: a rat cerebellar culture primarily formed by glial cells. Cultures of this kind are already being systematically investigated by synchrotron photoelectron spectromicroscopy [4], specifically to detect the distribution of artificially added metals like aluminum – suspected to play an important role in socially relevant pathologies like the Alzheimer.

The image formation process of micrographs of this kind includes several factors: microtopography, work function inhomogeneities, and above all the local chemical composition and properties [2]. These latter factors are known to play the most important role for micrographs like those of Fig. 3, which show different portions of a CsI surface [5]. This system is widely used for photon detection, and the present experiment models in a sense the detection mechanism, since it reveals the secondary-electron response stimulated by photon absorption. Such a response is clearly inhomogeneous along the surface, and it has been shown [5] to reflect the surface's chemical inhomogeneities.

As far as testing ELETTRA is concerned, the large volume of data like those of Figs. 1–3, taken in a short run, demonstrated that preliminary experiments are feasible even during this early commissioning stage, that multiple sequential microimages like those of Fig. 3 can be taken, and that the overall data quality was quite satisfactory considering that there was no time to optimize the experimental conditions.

In conclusion, the first phase of the commissioning of ELETTRA moved from the initial day to the first experimental test data in only three weeks, which is, to our knowledge, the most rapid commissioning ever of a

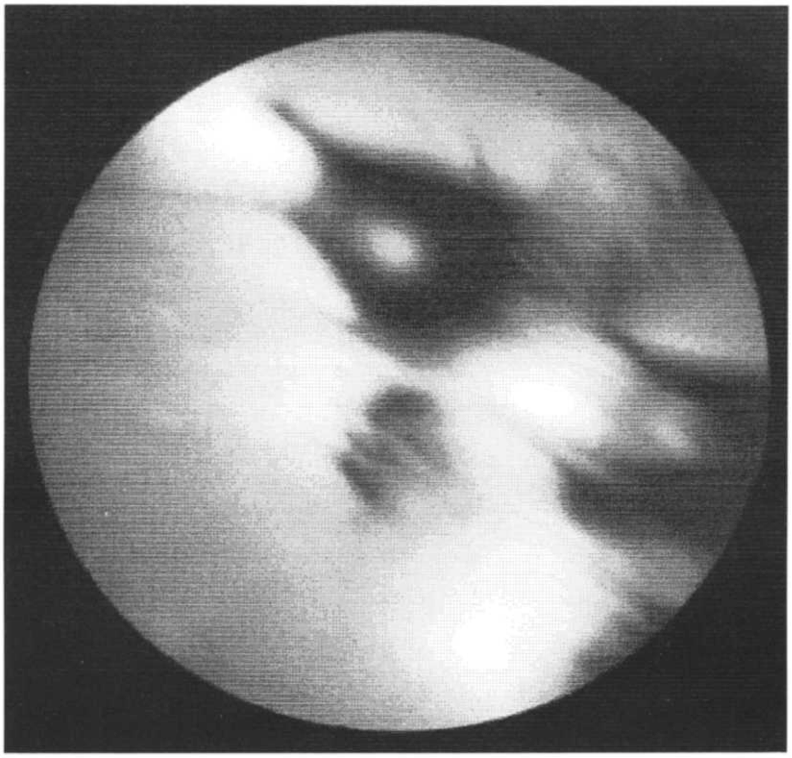

Fig. 2. X-ray photoelectron micrographs illustrating glia cells from a rat cerebellar culture. The diameter of the image is 200 μm.

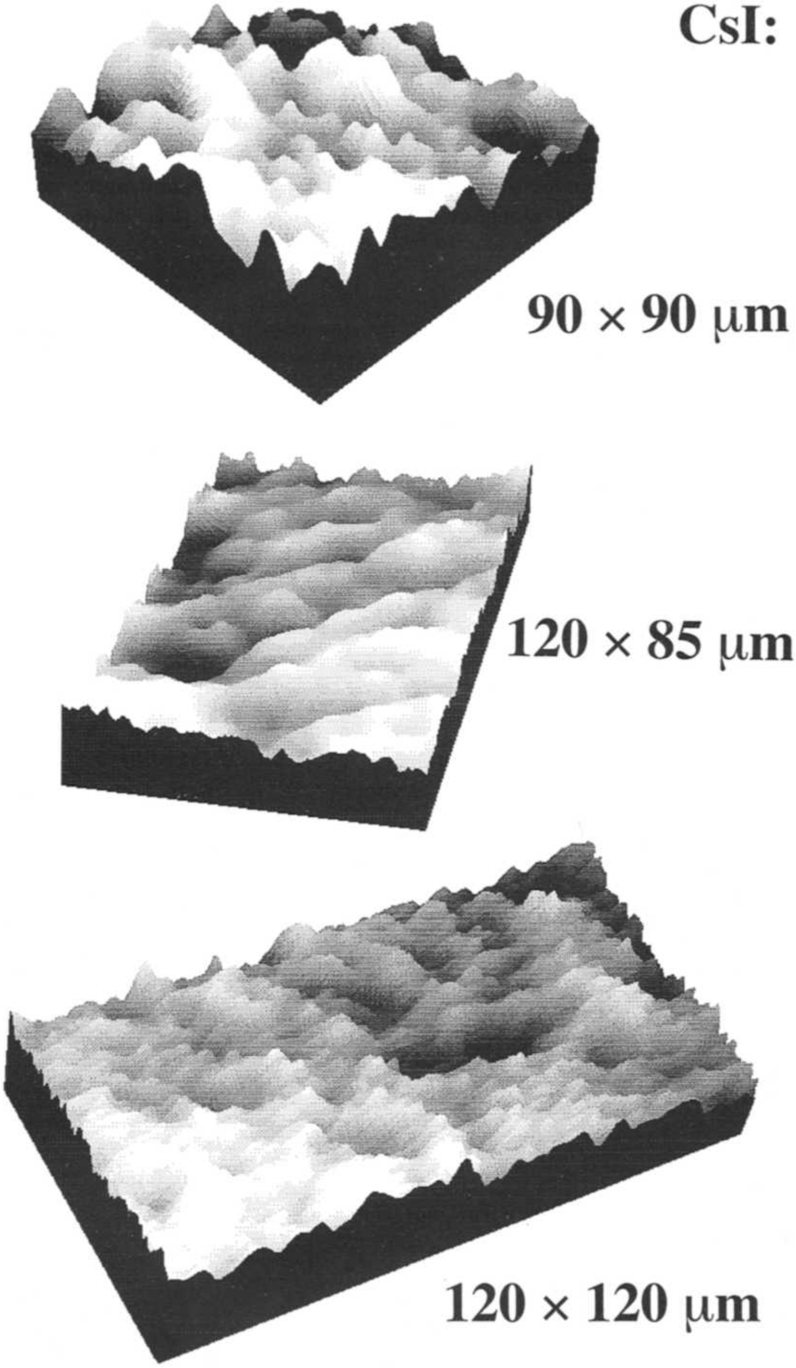

Fig. 3. X-ray photoelectron micrographs of the surface of a CsI sample, revealing chemical and topographic inhomogeneities which in turn are related to performance inhomogeneities in the detection of photons. The images were reconstructed in three-dimensions with the ©Spyglass software.

synchrotron radiation source. The test experiments were jointly conducted by external and internal groups, involving scientists from six different countries (Italy, Austria, Germany, Switzerland, the UK and the USA), thereby emphasizing the international vocation of this facility.

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