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ADONE WIGGLER BEAM LINES PROGRESS REPORT

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The new X-ray lines of the Adone Wiggler Laboratory are presented. The characteristics of the lines dedicated to solid state physics and biophysics are briefly reported. A more specific description of the X-ray lithography line is given.

1. Introduction

Since 1980 a conventional transverse wiggler magnet has been utilized in Frascati as a source of synchrotron radiation. The magnet characteristics and the properties of the emitted radiation are described elsewhere [1,2].

Until 1984 only one beam line, called BX1, was connected to the magnet, and the experimental apparatus for X-ray absorption spectroscopy was sited inside the Adone hall, with strong limitations in space and working conditions. Recently a new laboratory has been built; the BX1 line has been lengthened and new experimental stations have been installed. Moreover two new beam lines called BX2S and BX2L have been planned and will be completed at the beginning of 1986. The BX2S and BX2L lines will be dedicated to X-ray spectroscopy and to X-ray lithography respectively.

In this paper a description of the characteristics of the three lines is given. The new facilities for preparation and characterization of the samples and the system planned for the data acquisition and analysis are described.

2. Layout of the beam lines

In fig. 1 a schematic view of the existing BX1 line and of the two planned BX2S and BX2L lines is shown.

The BX1 line collects the radiation emerging along the wiggler axis. The BX2S and BX2L lines are split from a common line, called BX2, already completed, making an angle of 1.7° with the wiggler axis. This angle was chosen as a compromise between the necessity of space and the conditions imposed by the optical properties of the source. The wiggler, indeed, is a particular source which emits the radiation in an overall forward angle of about 4.5° in the horizontal plane. The beam of the BX2 line is split by a grazing incidence mirror; the reflected and straight beams are utilized for the BX2L and BX2S lines respectively.

Table 1
BX1 beam line characteristics

Distance source–monochromator	30 m
Window	100 μm Be
Horizontal angular acceptance	1 mrad
Monochromator	channel-cut (h = 5 mm)
	Si(111) – $\Delta E/E = 1.3\times10^{-4}$
	Si(220) – $\Delta E/E = 5.6\times10^{-5}$
Energy range	3–30 keV
Photon flux at 3 keV	3×10^{10} photons/ (s mrad mA) 0.1% b.w.

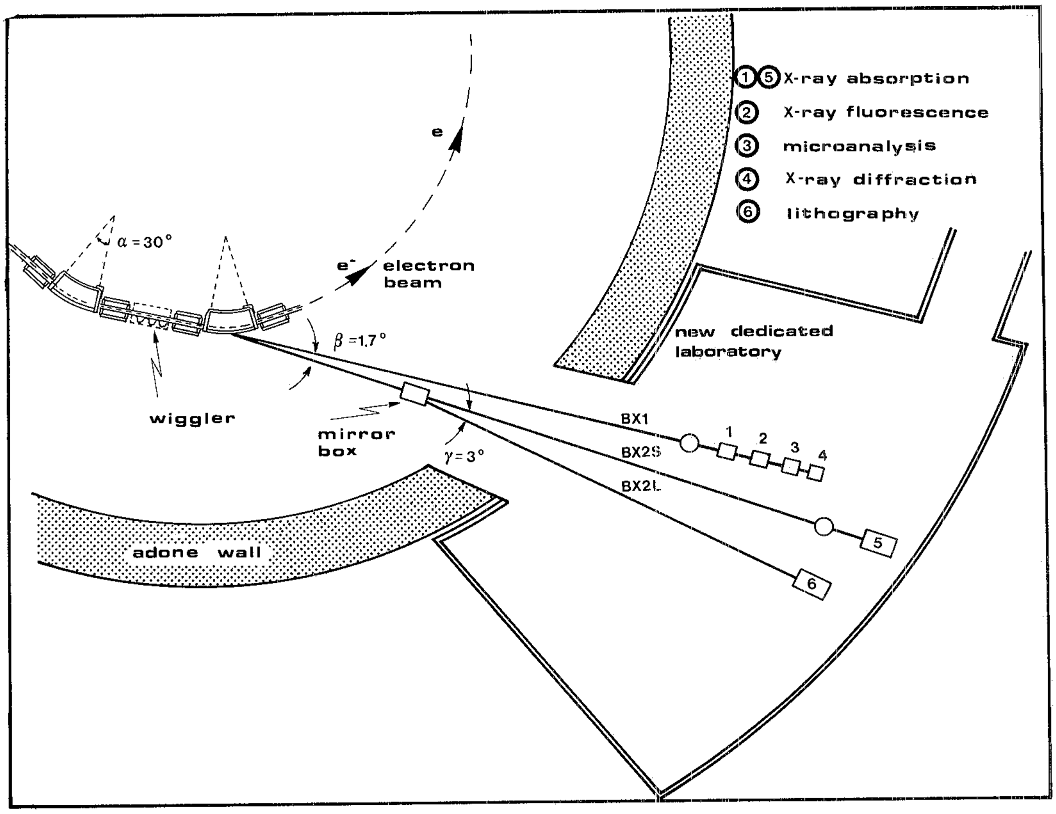

Fig. 1. Layout of the wiggler beam lines.

3. The X-ray spectroscopy beam lines

The main characteristics of the BX1 line are reported in table 1. They have been chosen to allow experiments with good resolution in the hard X-ray region. Table 2 reports the experimental stations installed serially after the monochromator (fig. 2). The geometrical and spectral characteristics of the BX2S line are similar to the ones of the BX1. The BX2S line will be mainly dedicated to X-ray fluorescence spectroscopy on biological samples (EXAFS, XANES, time resolved processes).

4. The X-ray lithography beam line

The BX2L line makes angles of 3° and 4.7° with the BX2S and the BX1 lines respectively (fig. 1). It is a line dedicated to X-ray lithography, and so it has been specially designed to match the beam characteristics to the requirements of that technique.

It is known that to obtain good contrast and uniform exposure of the X-ray resist the low and high energy part of the incident spectrum must be minimized [3]. Furthermore a good uniformity of the beam is required

Table 2
BX1 beam line: experimental stations

Station	Detector	Applications	Characteristics
X-ray absorption	Ionization chamber (filled with Ar, Kr, Xe)	EXAFS, XANES	Temperature control sample holder (100–370 K)
X-ray fluorescence chamber I	NaI (Tl) scintillators with photomultipliers	Fluorescence EXAFS	
X-ray fluorescence chamber II	Hyperpure Ge semiconductor	Trace element analysis	
X-ray diffractometer	NaI (Tl) scintillator with photomultiplier	Crystallography on proteins and polymers	Computer controlled 4-circle diffractometer

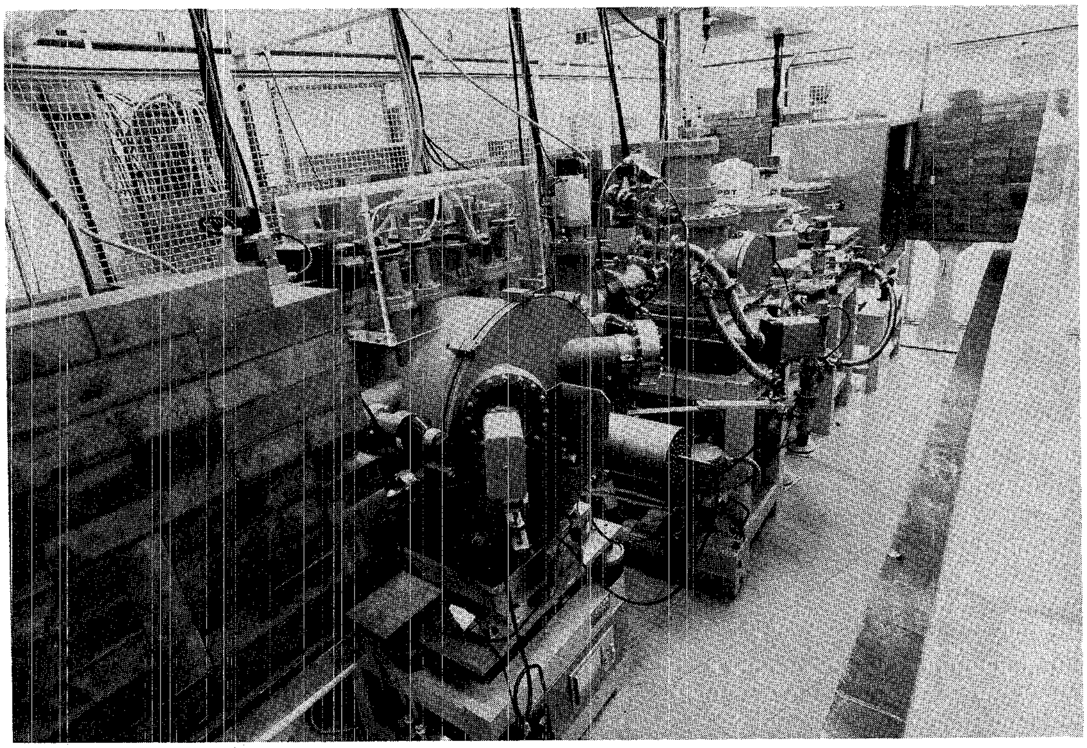

Fig. 2. Experimental stations at the BX1 beam line.

[4]. Finally, it should be useful to expose large area resist. Taking this into account the BX2L line has been planned to achieve the following characteristics:

(1) Energy range from about 1000 to about 3000 eV;
(2) Maximum uniformity of the intensity distribution on the resist;

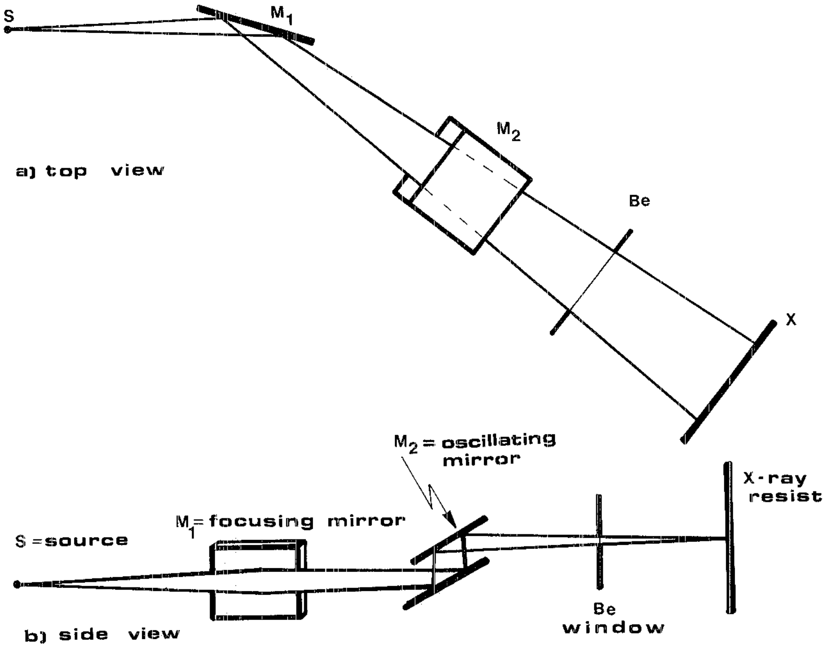

Fig. 3. Optical scheme of the BX2L beam line.

Table 3
BX2L beam line: first mirror characteristics

Material	gold coated quartz
Roughness	10 Å
Length	1 m
Grazing angle	1.5°
Cutoff energy	2.7 keV
Distance from the source	12.5 m
Distance from the sample	23.5 m
Optical properties	vertically focusing horizontally deflecting
Shape	cyclindrical
Radius of curvature	0.427 m

(3) Exposable area of about 7×7 cm^2 without moving the wafer;
(4) Fast exposure cycles.

These properties will be obtained with the following components:
(1) Cylindrical gold coated fused quartz mirror, vertically focussing and horizontally deflecting;
(2) A pair of flat gold coated fused quartz mirrors for the vertical scanning of the beam;
(3) 25 μm thick Be window.

A schematic view of the line is shown in fig. 3. Table 3 summarizes the main characteristics of the first mirror, located 12.5 m from the source. It is 1 m long, flat in the horizontal direction, with a 1.5° grazing angle, and collects 2 mrad of radiation. It gives a horizontal beam size of about 7 cm at the sample position, 36 m far from the source.

The mirror focuses vertically to give a small vertical beam size on the sample and so a more uniform flux in the vertical direction. The focusing is obtained through a cylindrical shape in the vertical plane. The radius of curvature is calculated to be $R = 42.7$ cm.

The cutoff wavelength, corresponding to a grazing θ_c angle, can be calculated by the equation:

$$\lambda_c = \theta_c \left(\frac{\pi}{n_e r_e} \right)^{1/2}, \qquad (1)$$

where n_e is the gold electron density and r_e is the classic radius of the electron (2.8×10^{-13} cm). In our case $\lambda_c = 4.7$ Å and $E_c = 2.7$ keV. This value is in good agreement with the X-ray lithography requirements.

To obtain the complete exposure of the wafer, without moving it, a vertical scanning of the beam is necessary. This is done by a flat mirror vertically deflecting and oscillating around an axis normal to the beam in the horizontal plane. An oscillation of $\pm 0.15°$ around the grazing angle of 1.5° allows the complete scan of the wafer when the exposure chamber is about 13 m from the mirror. Calculations show that these small angular oscillations do not cause any significant

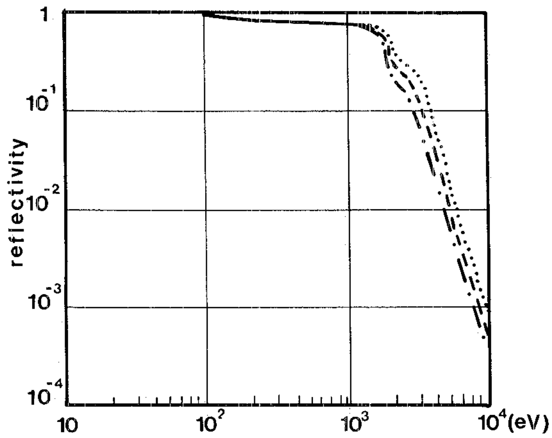

Fig. 4. Variation of the reflectivity due to the mirror oscillations: $\phi = 1.35°$ (· · ·), $\phi = 1.5°$ (— — —) and $\phi = 1.65°$ (–·–).

change in the cutoff wavelength and in the spectral properties of the incident radiation (fig. 4).

To obtain only a small change in the vertical beam position a second parallel grazing incidence flat mirror is placed very close to the oscillating one. In this case the net vertical displacement of the beam is given by the equation:

$$d = 2h \cos\theta \simeq 2h, \qquad (2)$$

where h is the vertical distance between the mirrors. This distance is only few centimeters.

As final optical element of the line, a 25 μm thick Be window is placed in front of the exposure chamber for two purposes:
(1) To reject the soft part of the spectrum;

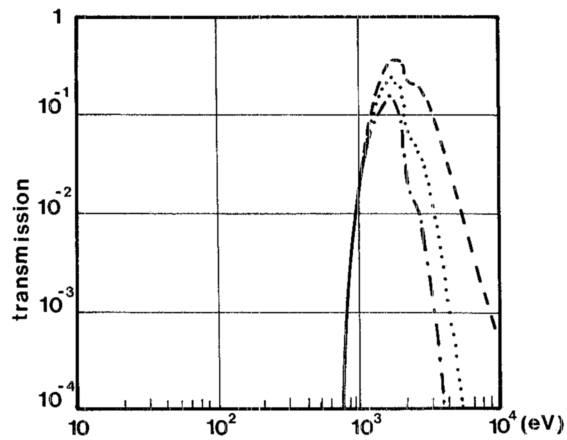

Fig. 5. Transmission of the 25 μm beryllium window plus gold coated mirrors ($\phi = 1.5°$): (— — — —) one mirror (· · · ·) two mirrors, (–·–·–) three mirrors.

(2) To separate two regions working in different vacuum conditions.

As we already mentioned, the low energy part of the spectrum is not useful for the exposure of the resist.

If the condition $\rho_R \mu_R\ (h\nu) t_R \ll 1$ (where ρ_R, μ_R, t_R are the density, the mass absorption coefficient and the thickness of the resist) is not satisfied, the X-ray flux is not constant throughout the resist, so the power absorbed per unit depth is not constant. This causes a nonuniform dissolution rate of exposed resist in the developer as a function of depth. This happens, for typical resist (PMMA, PCMS) for energies below 500 eV.

A Be filter 25 μm thick rejects energies below 1000 eV. The window separates also the high vacuum region (10^{-9} Torr), connected to the accelerator, from the exposure chamber where the pressure can be also four orders of magnitude higher (10^{-5} Torr). This pressure difference does not cause any mechanical stress to the window, allowing very fast duty cycles.

The calculated transmission of the overall system mirror–Be window is shown in fig. 5.

5. Sample preparation and characterization

A new laboratory, particularly equipped for the preparation and characterization of biological samples, has been completed. The aim of this facility is to provide complete instrumentation to allow the examination of the samples before and after an experimental run and the preparation of particularly instable samples immediately before the exposition to the beam.

The instrumentation consists of:

(1) Cold room;
(2) Super-speed centrifuge (20 000 rpm);
(3) Liophilizer;
(4) Electrophoretic and column chromatography kit;
(5) Two spectrophotometers in the UV (190 : 800 nm) and IR ($2.5 \times 10^3 - 5 \times 10^4$ nm) range.

This instrumentation allows biological sample extraction and purification and biophysics experiments.

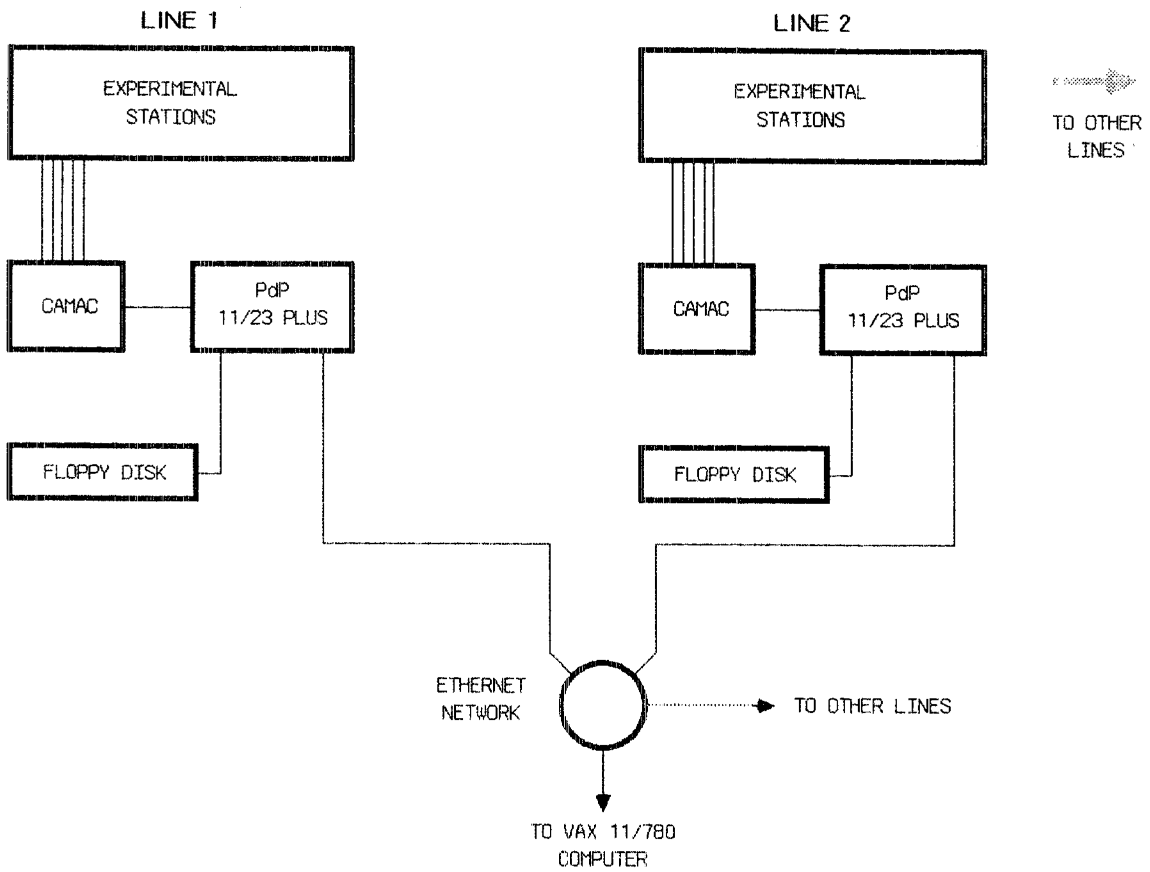

Fig. 6. Planned system for acquisition and data analysis.

6. Data acquisition system

A complete system for data acquisition and analysis has been planned and partially assembled (fig. 6). The control of the experimental stations and the data acquisition are carried out by a dedicated computer (PDP 11/23 PLUS) through a CAMAC system. This system ensures a high degree of standardization and simplifies the implementation of new experiments. The link of the computers to the ETHERNET network of the Frascati National Laboratories is planned. In this way the data analysis will be performed utilizing the VAX 11/780 main computer of the laboratories. This allows the line computers to be completely oriented to the experimental environment. The users can also bring their data on floppy disk or magnetic tape for later analysis.

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