Beamline 10.0.1 – an undulator beamline for high-resolution spectroscopy in the 17-340 eV range

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INTRODUCTION

Beamline 10.0.1 was installed to support programs in high temperature superconductivity research and in atomic and molecular spectroscopy. The beamline was constructed and saw its first light in June 1998. A new 10cm period undulator was constructed by the ALS Insertion Device Group and installed in the sector 10 straight section of the ALS storage ring during the spring 1998 shutdown. A specification for the personnel safety shutter/photon shutter assembly was developed by the ALS Mechanical Engineering group and the fabrication contract awarded to Oxford Instruments. The shutter assembly was also installed during the spring shutdown. The majority of the rest of the beamline was moved from Beamline 9.0.1 during the period of March – June 1998. New mirrors were fabricated to replace the horizontally focusing M1 mirror that remained with BL9.0.2 and to produce small horizontal foci in the two side branches of the beamline.

OPTICAL LAYOUT

The optical layout of beamline 10.0.1 is similar to that of its predecessor, BL9.0.1. Spherical mirrors and gratings deflect, focus, and disperse the radiation from the U10 undulator.

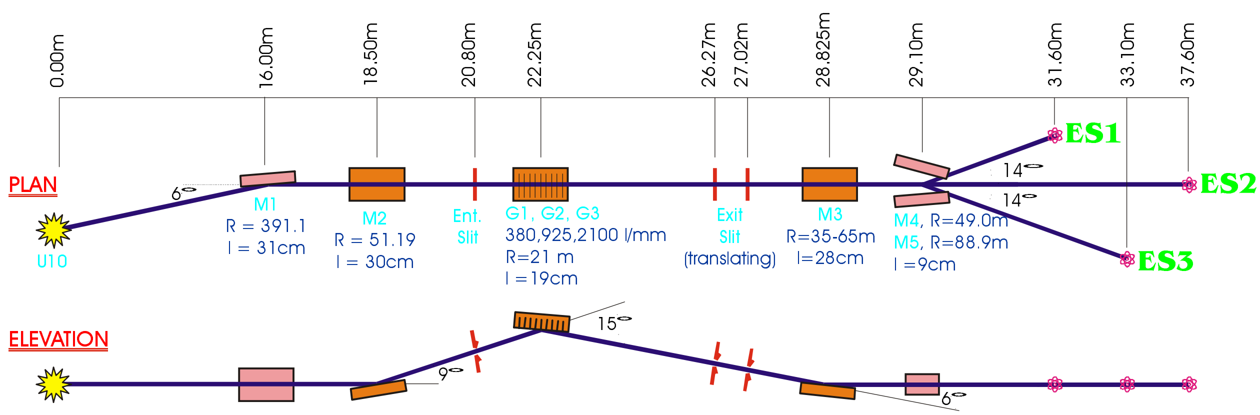

Figure 1. Schematic layout of Beamline 10.0.1 optics in plan and elevation views. The numbers indicated at the top of the figure indicate the distance of the center of the optical element from the center of the undulator along the optical path. Three different experimental end stations are available with horizontal foci at different distances from the refocusing optics as indicated.

Radiation from the undulator is horizontally focused by the water cooled M1 mirror to a point 28.4m downstream from the mirror. While this location is actually outside of the ALS building, it was chosen to provide a higly collimated beam with a maximum width of 1.5mm at the position of the ion beam experiment on the central branch line. The long focal length of the mirror also plays a role in the demagnification of the M4 and M5 mirrors for the side branches. The water cooled M2 mirror focuses the undulator radiation vertically and forms an 8:1 demagnified image of the source at the entrance slit of the monochromator. The demagnification is crucial to the performance of the beamline as it permits all of the undulator radiation to be passed through the small entrance slit required for high spectral resolution. The entrance slit opening is variable over 0 – 150μm to allow a suitable compromise between intensity and resolution.

One of three water cooled diffraction gratings can be positioned in the beam path following the entrance slit, depending on the photon energy required. The low energy grating with a ruling density of 380 lines/mm covers the photon energy range from 16 to 61 eV, the medium energy grating with a ruling density of 925 lines/mm covers the range from 40 to 150 eV, and the high energy grating with a ruling density of 2100 lines/mm covers 90 to 340 eV. The energy range of each grating is limited both by the geometry of the beam path and the length of travel of the exit slit. The exit slit, which translates along the beam path to remain in the focus of the grating as it is rotated to select the appropriate wavelength or photon energy, has a variable opening from 0 to greater than 500 μm. The exit slit is the first uncooled component of the beamline. Following the power filtering of the upstream mirrors and the dispersion of the gratings, the power density of the photon beam at the exit slit is sufficiently reduced to allow the use of uncooled optics.

The variable radius M3 mirror vertically refocuses the light and forms an image of the exit slit into the experimental apparatus. The mirror is bent by a flexural hinge with a large piezo crystal. The radius of the mirror is variable from 35-65m allowing the focus to be moved between the end-stations. Two horizontally focusing deflection mirrors can be inserted into the beam to deflect it at a 14° angle into one of two side branches of the beamline. These mirror use the image of the first horizontal mirror in the beamline (the M1 mirror) as a virtual object and form a demagnified image 2.5m and 4.0m downstream for the outboard and inboard branches respectively.

Table 1. Parameters for the optical elements within beamline 10.0.1.

Mirror	Coating	Cooling	Deflection	Deflection	r (m)	r' (m)	R (m)
M1	Ni	Water	Horizontal	9°	16.0	28.4	391.1
M2	Ni	Water	Vertical	9°	18.4	2.3	51.2
325 l/mm	C	Water	Vertical	15°	1.45	4.00–4.77	21
925 l/mm	C	Water	Vertical	15°	1.45	4.00–4.77	21
2100 l/mm	Ni	Water	Vertical	15°	1.45	4.00–4.77	2
M3	Ni	None	Vertical	6°	1.8-2.6	2.5 – 8.5	35-65
M4	Au	None	Horizontal	14°	-15.3	2.5	49.0
M5	Au	None	Horizontal	14°	-15.3	4.0	88.9

FLUX OF BEAMLINE 10.0.1

No significant changes are expected in the flux of beamline 10.0.1 relative to its predecessor, beamline 9.0.1 as they use the same source, mirror angles, mirror coatings, slits, and gratings. The transmitted flux of the beamline was evaluated for slit settings corresponding to a resolving power (E/ΔE) of 10,000. The flux of the undulator was calculated at 400 mA of stored current in the storage ring at 1.9 GeV. Geometrical factors corresponding to the masking of the beam by the entrance and exit slits and the overfilling of the grating at some energies were included in the calculation. Reflectivities of the mirrors were obtained from the CXRO web site (www-cxro.lbl.gov) and the grating efficiency calculated by a scalar theory formula. Combining all of these factors together yields the data presented in figure 2. The two curves for each grating correspond to the flux on the central and side branches and result from the reflectivity of the 7° horizontal focusing mirror. Note that this mirror has a cut off starting at 140 eV where the reflectivity drops from approximately 80% to less than 20% above 200 eV. Notice that the flux is greater than 10^{12} photons per second over most of the range covered by the beamline.

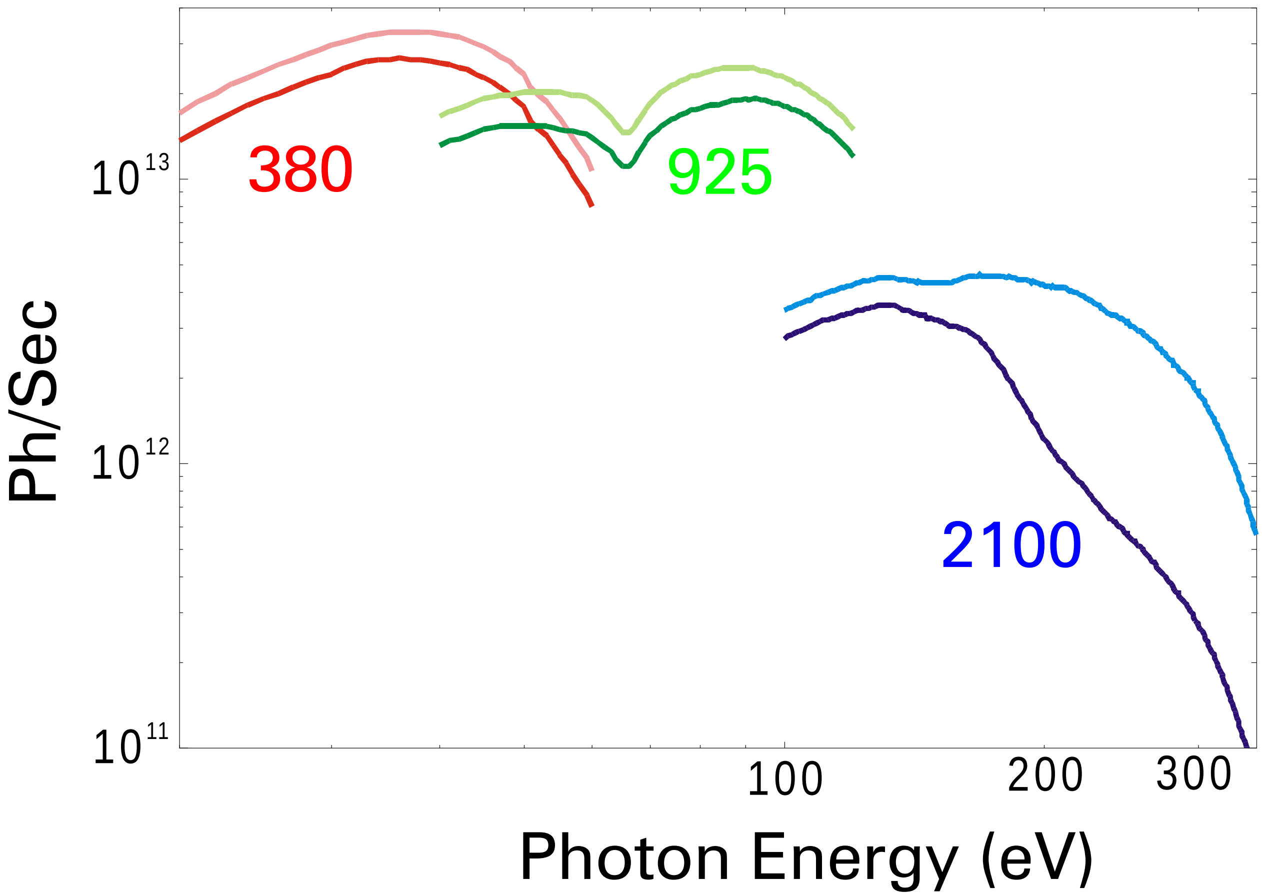

Figure 2. Flux of radiation from beamline 10.0.1 at a resolving power (E/ΔE) of 10,000. Details of the factors included in the calculation are described in the text. There are two curves for each grating (as indicated on the figure by their line densities; 380, 925, 2100 lines/mm). The upper curve corresponds to the flux on the central branchline and the lower curve the flux on either of the side branch lines.

RESOLUTION OF BEAMLINE 10.0.1

The resolution of beamline 10.0.1 should be unchanged from the previous beamline 9.0.1 since none of the resolution determining elements have been changed. The resolution of a spherical grating monochromator is determined by the size of the slits, the dispersion of the grating and contributions from various abberations. In figure 3 the resolution of beamline 10.0.1 is calculated for slit settings of 10 μm. In addition to contributions from the slits, the effect of the coma abberation from the grating is included in the resolution evaluation. Contributions from the slits and coma are indicated separately by the two lighter lines for each grating and the two are added in quadrature to yield the total resolution of the beamline.

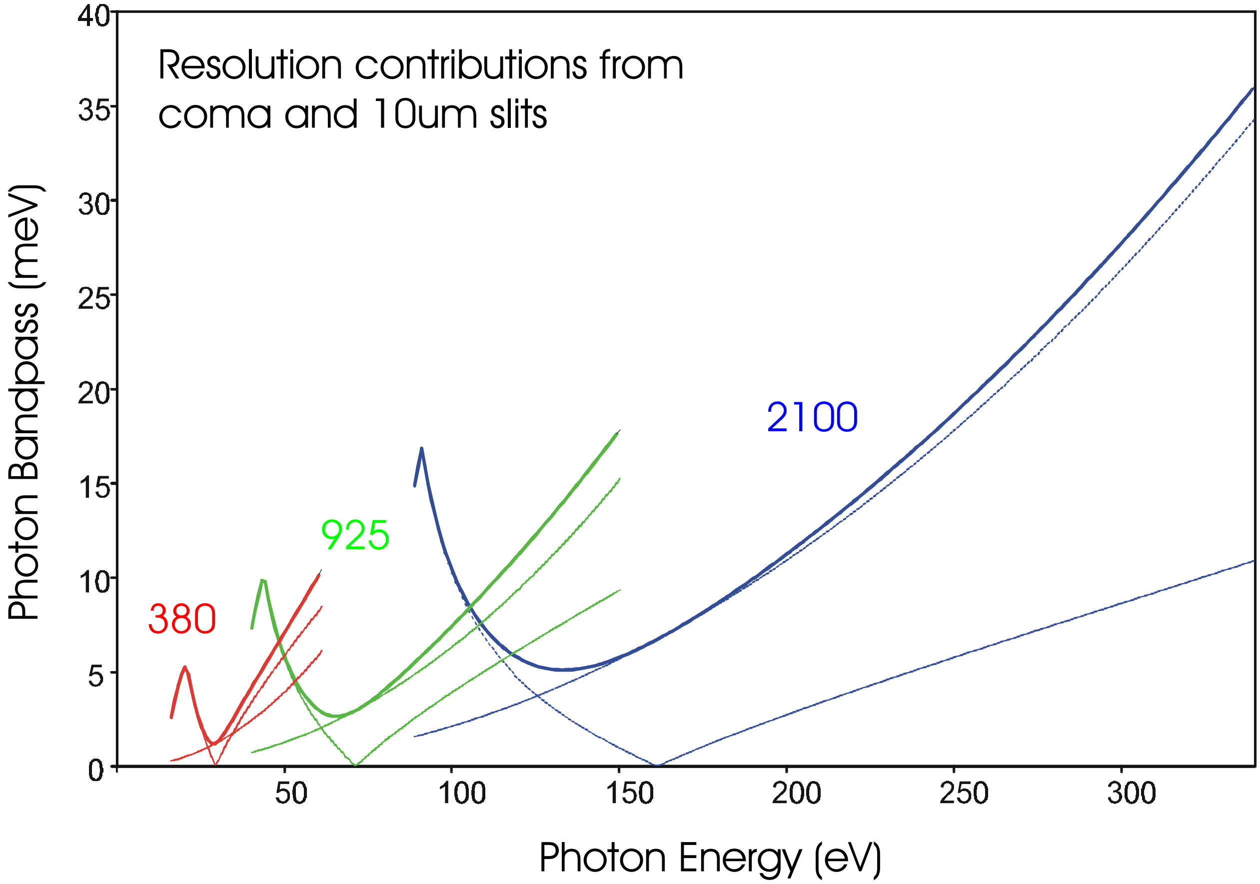

Figure 3. Contributions of 10 mm slits and coma to the resolution of beamline 10.0.1 for each of the three gratings. The contributions of the slits are shown by the light lines which increase with photon energy and the contributions from grating coma by the light lines which dip near the cneter of the range of the grating. The sum of the two contributions is shown by the heavier line.

It is apparent that there is a minimum in the coma contribution for each grating near the center of its range. This coma zero occurs when the positions of the slits and grating angle are at the Roland circle geometry which occurs at approximately 29, 70 and 162 eV for the 380, 925 and 2100 line/mm gratings respectively.

ACKNOWLEDGEMENTS
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