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# Time-Resolved Spectral Measurements Above 80Å*

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# Time-Resolved Spectral Measurements Above 80 Å*

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## Abstract

We have made time-resolved spectral measurements above 80 Å from laser-produced plasmas. These are made using a transmission grating spectrograph whose primary components are a cylindrically-curved x-ray mirror for light collection, a transmission grating for spectral dispersion, and an x-ray streak camera for temporal resolution. A description of the instrument and an example of the data are given.

We have built a spectrograph to time resolve the spectrum above 80 Å from laser-produced plasmas. Several possible schemes using high-powered lasers have been identified that produce x-ray lasing lines in the 80 Å to 300 Å range.[1] This spectrograph has been built to measure the output from these targets.

The principal components of the spectrograph are a cylindrically-curved x-ray mirror for light collection, a transmission grating for wavelength dispersion, and a soft x-ray streak camera for x ray detection. These have been combined to produce an instrument having high spectral resolution, $E/\Delta E > 200$, continuous wavelength coverage from 80 Å to 300 Å, good time resolution, ∿20 psec, and high sensitivity, $\sim 10^{20}$ photons/sec-sr. In addition, because an application is to measure x-ray lasing output, we have devised an optical alignment system which can accurately point the instrument to the target with an accuracy of less than one milliradian.

A schematic of the instrument design is shown in Fig. 1. X rays from the target are collected and focused a the detection plane by a cylindrically-curved grazing incidence x-ray mirror. The mirror acts like one element of a Kirkpatrick-Baez x-ray microscope producing a line focus perpendicular to the plane of dispersion.[2] The mirror has an eight meter radius of curvature and operates at an angle of incidence of $4^{0}$. It is 68 cm from the target midway between the target and detection circle. This produces a magnification of unity. Spherical aberrations for these conditions are estimated to be less than 10 μm, which is much less than target sizes.

The dispersing element of the system is a free-standing transmission grating placed directly behind the x-ray mirror.[3] Figure 2 is a photograph of the mirror-grating assembly. The view is looking from the target towards the instrument. The grating disperses the x rays from the zeroth order established by the reflected direction of the mirror. The grating used for the experiment has a periodicity of 2000 Å and a line-to-space ratio of 1.2. The grating is 62 cm from the detection plane for a dispersion of 3.2 Å/mm. The active area of the grating is about 3 mm diameter and the dimensions of the mirror overfill the grating area with x rays.

An LLNL-designed soft x-ray streak camera is used as a detector.[4] The camera is designed to pivot around the grating from the 0.0. to 9° to allow continuous coverage through the desired wavelength region. The streak camera and its mounting assembly are shown in Fig. 3. The view is looking from behind the instrument. The LLNL streak camera has a temporal response of 20 psec, providing good time resolution for the experiment. The entrance slit of the streak camera is aligned with the dispersion plane of the grating. The 1.2 cm slit allows a 35 Å portion of the spectrum to be measured at one time. To cover other regions of the spectrum, the streak camera must be moved along the detection plane. The 100 μm resolution along the cathode slit

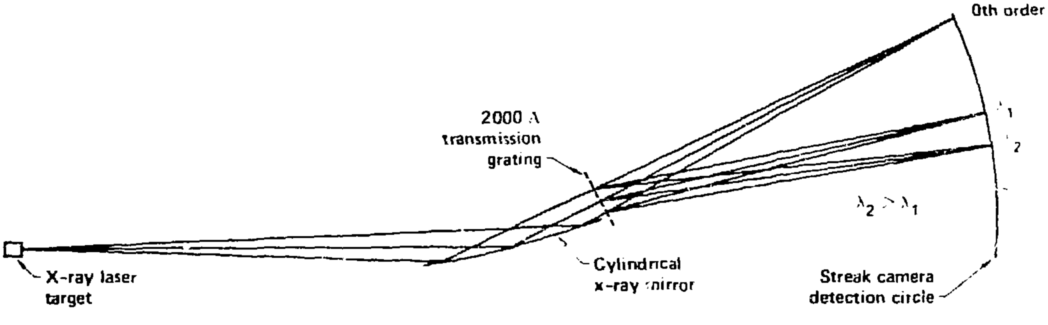

Fig. 1 Schematic of the transmission grating streaked spectrograph for measuring spectra above 80 Å.

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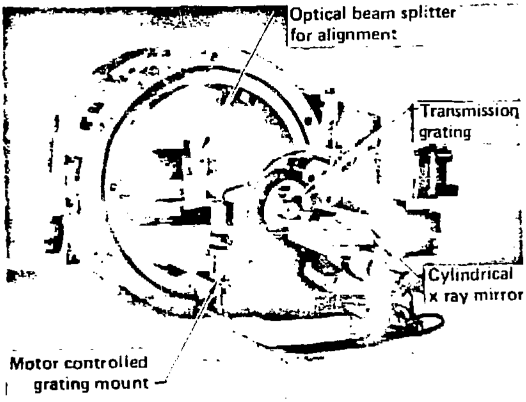

Fig. 2 Photograph of the transmission grating x-ray mirror assembly.

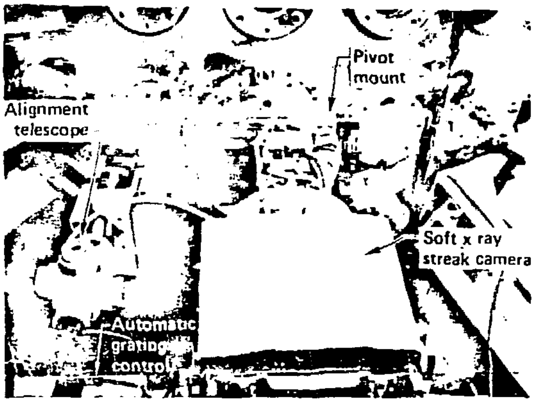

Fig. 3 Photograph of the x-ray streak camera and pivot mount assembly.

translates to a wavelength resolution of 0.32 Å. Neglecting source size effects, the resolving power, $E/\Delta E$, is 250 for 80 Å and increases for the longer wavelengths.

The efficiency of the system is the throughput of the system combined with the efficiency of each component of the system. The mirror is coated with Ni and has a reflectivity calculated to be 75% or greater at these angles and energies. The grating efficiency has not been measured, but it is calculated to be 10% diffracted into first order. Because of super structure on the grating this efficiency is reduced to an efficiency of 2.5% of the incident light. We are now measuring the streak camera efficiency, but estimates can be made using previous streak camera calibrations accounting for the photocathode dependence. We estimate that we should be able to see lines whose intensity is greater than $10^{20}$ photons/sec-sr.

For these experiments the photocathode is 900 Å CsI film deposited on a 1000 Å parylene substrate. A 50 Å layer of Al is placed over the parylene to increase electron conduction. CsI has been shown to have high sensitivity in previous studies.[5] We have estimated the quantum efficiency of the cathode and this estimate is shown in Fig. 4. For these estimates we use the measured front surface yields of CsI[6] and the expression by Henke, et. al.,[5] to translate these to rear surface yields, as are needed for x-ray streak camera efficiencies. The calculated back-to-front ratio is also shown in Fig. 4. It is interesting to note that the large increase in the CsI yield around 100 Å observed in the front surface yield is moderated in the rear surface yield. This yield is due to increased absorption in the CsI, which decreases the number of photons reaching the rear surface of the cathode.

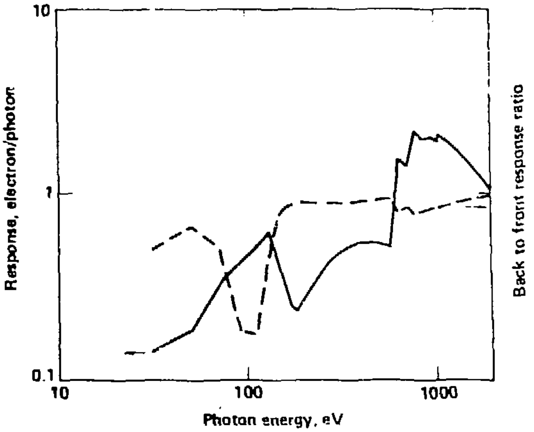

Fig. 4 Photocathode response of 900 Å CsI used in the experiment.

An example of the data and demonstration of the instrument performance is shown in Fig. 5. The spectrograph is viewing the edge of a Formvar foil irradiated on both sides by 100 ps pulses of 450 Joules of 0.525 μm light focused in a cylindrical spot 2 mm by 12 mm. The intense line feature in the middle of the cathode is the 3p-2s transition from OVIII at 102.4 Å. It is seen that it turns on early during the irradiation pulse and persists for about 2 ns. Spectra at two different times are shown in Fig. 6. The upper trace is early in time during the laser pulse. The line is relatively sharp with a high continuum level. Later in time, as shown in the lower trace, the continuum level is reduced, but the line is as intense, although it is slightly wider. It appears that the emission continues after the irradiation as the foil blows up. As the foil expands the line broadens due to the larger source.

In summary, we have built a streaked spectrograph for time resolving laser plasma spectra above 80 Å. It uses a cylindrically-curved mirror for light collection, a transmission grating for spectral dispersion, and a soft x-ray streak camera for time-resolved detection. We are presently calibrating the system, but we estimate that we can measure lines whose intensities are on the order of $10^{20}$ photons/sec-sr. An example of the data is given showing strong line emission in this region from laser-produced plasmas.

The authors would like to acknowledge Dr. Andrew Hawryluk and his colleagues at MIT's Submicron Structures Laboratory for supplying the transmission gratings.

Fig. 5 Example of the streak camera data for the OVIII 3p → 2s line from a Formvar foil.

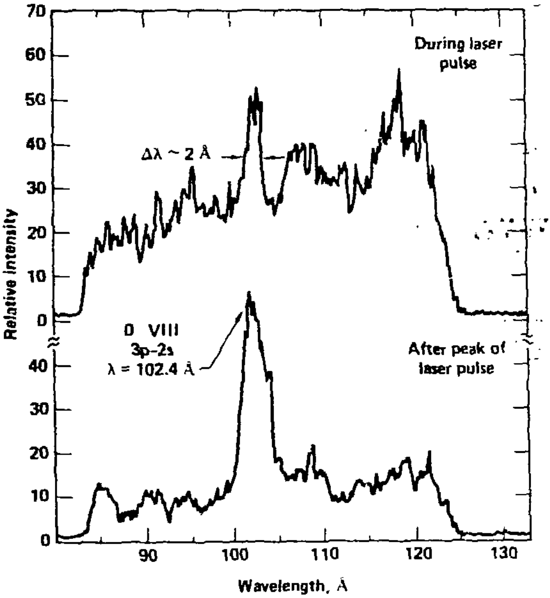

Fig. 6 Time-resolved spectra showing the OVIII 3p → 2s emission at different emission times.

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