Measuring Your EUV Laser

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For manufacturers and others who have acquired extreme-ultraviolet (EUV) lasers recently, some test and measurement are in order. At the very least, you will want to measure the exact wavelengths emitted. Perhaps you will want to select one wavelength and use it to interact with a sample in some experiment. Both jobs call for spectrometers.

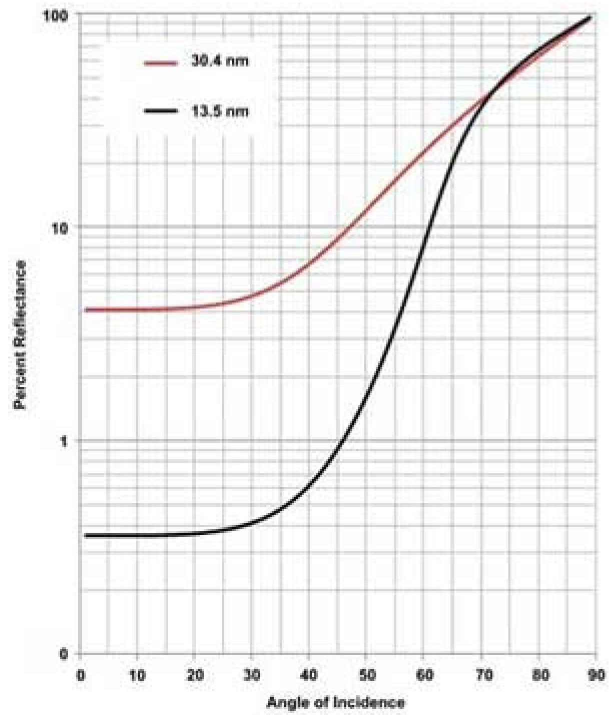

Figure 1. *Reflection of gold vs. angle of incidence.*

At short wavelengths, designs such as the Czerny-Turner are not viable. This spectrometer has at least three reflective surfaces, all at near-normal incidence angles. Even with a vacuum enclosure and state-of-the-art reflective coatings, it is not useful at wavelengths of <110 nm.

Fortunately, designs exist that use diffraction gratings on concave substrates. These reduce the optical system to one reflective surface that simultaneously disperses and focuses spectra. In a suitable vacuum enclosure, they work to wavelengths of slightly <30 nm, even when using near-normal incidence angles. Spectral diagnosis of laser output wavelengths is relatively fast and easy with these instruments. Appreciable wavelength regions in the vacuum-UV (VUV) can be measured simultaneously when equipped with microchannel plate intensifiers or direct-detection CCD detectors. These designs also are useful for scanning monochromator applications and for "dialing in" a particular wavelength for subsequent focus optics and sample illumination.

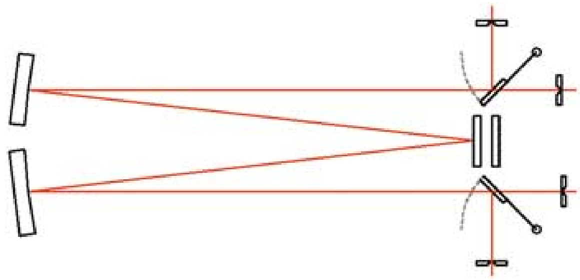

Figure 2. *Czerny-Turner design uses multiple reflective surfaces and vacuum enclosure for wavelengths of >110 nm.*

Spectrometers for work at wavelengths of <30 nm also may use diffraction gratings on concave substrates. Angle-of-incidence changes from normal to grazing boost reflective efficiency (see Figure 1, the chart of modeled data, which underscores the requirement for use of spectrometers in the soft x-ray and EUV, particularly when multiple optics are used). By using a 2° or 3° grazing angle of incidence, reflective efficiency can be >80 percent at wavelengths as short as 8 nm.

Some soft-x-ray and EUV spectrograph gratings have been designed and produced for dedicated regions. They can render spectral measurements of laser output in a fixed region relatively simple. More versatile, Rowland circle grazing incidence spectrometers are analytical tools for greater wavelength regions and can work as scanning monochromators or spectrographs, depending upon selected detection equipment; however, neither is ideal for dialing in an EUV wavelength and illuminating a sample.

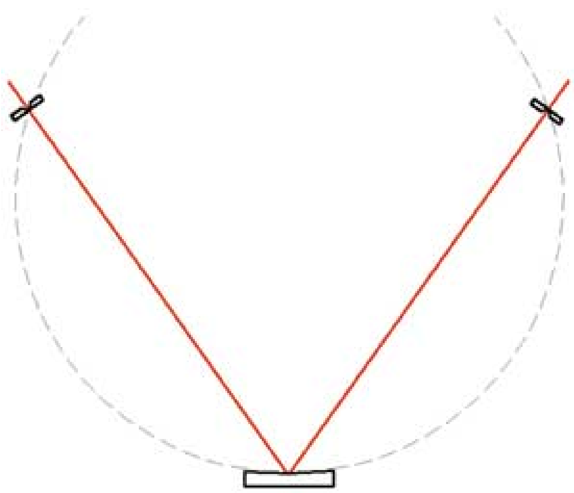

Figure 3. *Seya-Namioka design uses concave diffraction grating to simultaneously disperse and focus. Useful for wavelengths of >30 nm.*

To accomplish this, more complex instruments with concave spherical, toroidal or off-axis parabolic collimation and focusing mirrors, in combination with plane diffraction gratings, often are used. These can become quite large, complex and, eventually, “beam line” instruments. Because optical aberrations contribute significantly to instrument performance at grazing incidence angles, care must be taken to adopt suitable designs and to plan for the best possible optics. Done well, these select a discrete EUV laser wavelength with good spectral resolution and focus to a sample; e.g., in a photoelectron spectrometer.

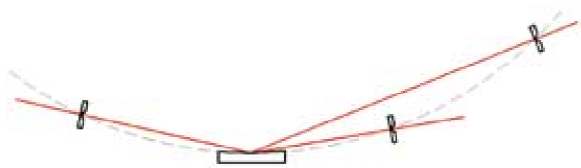

Figure 4. *Rowland circle grazing incidence design works at 2° or 3° angle of incidence and is useful for wavelengths of >1 nm.*

Another important design consideration occurs when pulse broadening is of concern. A diffraction grating, rotated to tune for a particular wavelength, can introduce appreciable broadening of narrow laser pulses. To minimize the broadening introduced by rotation of a single diffraction grating, spectrometers may be built as doubles. Two instruments work together to select wavelengths, while their mirrored optical paths negate broadening effects. In recent years, developments include double off-plane grazing incidence instruments that further minimize residual broadening effects.

Spectrometers currently are available for much of the soft x-ray, extreme UV and VUV regions, although not always in the form in which we are accustomed to seeing. Selecting a spectrometer requires prioritizing analytical goals, wavelength range, spectral resolution, dispersion and possibly optical aperture requirements in light of experimental needs. Shorter wavelengths require ever more care in selection of optical schemes to maintain efficiency and performance.

The optical designs pictured in Figures 2 through 4 demonstrate the progression from the multisurface normal-incident Czerny-Turner – often used for visible spectroscopy – to the single-surface grazing-angle spectrometers – useful in the soft x-ray and EUV regions.

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Extreme Ultraviolet: A New Frontier for Lasers

Hank Hogan, Contributing Editor

Advances in compact EUV lasers could benefit industries from semiconductor manufacturing to medicine.