Soft X-Ray Emission from a Laser-Produced Carbon Plasma

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Under specific conditions laser produced plasmas can be created which emit radiation only in a few well isolated spectral lines in the soft X-ray region. Using a Nd:YAG laser system with a pulse length of 170 ps and a pulse energy of 215 mJ in a focus with a diameter of 50 μm on a plane carbon target, a plasma was created emitting mainly the resonance series of hydrogen- and heliumlike carbon ions. The emission lies in the region between 300 and 500 eV and is of special interest to X-ray microscopy as it lies within the "water window". For the C V line at 308 eV the contrast ratio between the emission in the spectral line and in the continuum adjacent to that line is better than 500. The absolute emission in this line is 5.5x10^{12} photons/sr per pulse. The reproducibility of the radiation emission is about 15%.

1. Introduction

A basic requirement to do X-ray physics is the availability of a suitable X-ray source. Modern electron storage rings in combination with advanced beamlines offer great opportunities for X-ray physics, but due to the high costs of building and operating such systems the access will always be limited.

Alternative X-ray sources such as laser produced plasmas are therefore of great interest for example in the fields of X-ray microscopy or X-ray lithography. While a lot of information is available about the X-ray emission in general, quantitative data of the radiation emission in the soft X-ray region are difficult to obtain.

As laser produced plasmas compete with synchrotron radiation sources, in many experiments the conditions were optimized to produce clean continuum radiation and to avoid line radiation [1,2]. For applications especially in X-ray microscopy line radiation emission is of advantage for the following reasons.

For X-ray microscopy optical imaging is required. To avoid complex grazing incidence optics it is desirable to use zone plate optics or multilayer coated normal incidence optics. In the case of zone plates as well as multilayer optics only radiation of a specific small wavelength interval can contribute and all other radiation is either useless or even harmful. The aim is therefore to concentrate as much energy into one particular emission line with as little radiation in the vicinity of the line as possible.

A suitable element for use as target material is carbon, as the emission lines of the hydrogen- and heliumlike carbon ions lie in the water window between 280 eV and 520 eV.
2. Experimental

At the VUV radiometric laboratory of PTB at the Berlin electron storage ring BESSY a special beamline has been set up for the quantitative characterization of laser produced plasmas in the photon energy range from 250 to 1800 eV [3]. The spectral radiation emission of the laser produced plasma is determined by comparison with the calculable spectral radiation emission of the storage ring. An imaging spherical mirror can be rotated to focus either the radiation from the tangent point of the storage ring or from the laser produced plasma into the entrance slit of a 5m rowland-circle monochromator.

To account for the different degrees of polarization of both sources, the complete system can be rotated around the optical axis to allow measurements in both s- and p-polarization. A detailed description of the method is given in [2].

The laser system consists of an active/active mode-locked Nd:YAG system working at 1.064 μm with a pulse length of 100 ps and longer and pulse energies of up to 300 mJ with repetition rates of up to 10 Hz. Typical operation parameters for the carbon experiment were 270 mJ in 170 ps at 5 Hz. The laser radiation was focused on a plane carbon target in a vacuum chamber using a combination of two spherical lenses with an effective focal length of 85 mm. The laser focus on the target was determined to about 50 μm diameter. A thin glass plate was used inside the target chamber to protect the entrance window, which was AR coated like the

![Graph](image)

**Fig. 1:** Spectrum of a laser produced carbon plasma. $I/I_{\Delta E}$ is the radiant emission in photons/sr within the bandwidth of the monochromator ($\Delta E = 2.0$ eV at $E = 300$ eV, $\Delta E = 4.4$ eV at $E = 450$ eV), time integrated over one pulse. The expected lines and the ionization energies (dotted) of C V and C VI are shown below.