Compact soft x-ray spectrometer for laser-matter studies

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Application Note

Introduction

A convenient way to produce xray radiation is based on the interaction of intense laser pulses with matter. Especially nano-sized particles are interesting targets since the interaction of strong laser fields with nanoparticles can in principle be fully analysed: As result of the strong-field ionisation and plasma formation, energetic particles and short wavelength radiation are emitted [1]. With the advent of table top laser systems delivering ultra-short and intense pulses, these experiments on nanoparticles can be conducted in the own lab. However, basic research on x-ray emission of laser induced nano-plasma provide only weak signals, which is a challenge for detection with respect to quantum efficiency and noise level.

We present a compact x-ray spectrometer using the Andor Back Illuminated CCD detector Newton DO940P-BN satisfying the request for a suitable analysing tool.

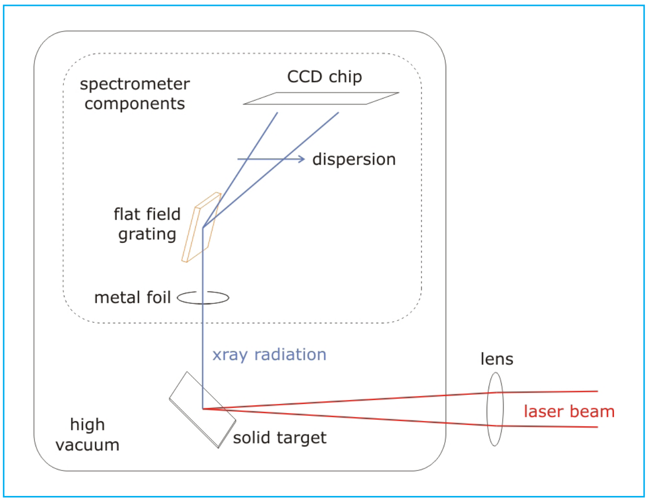
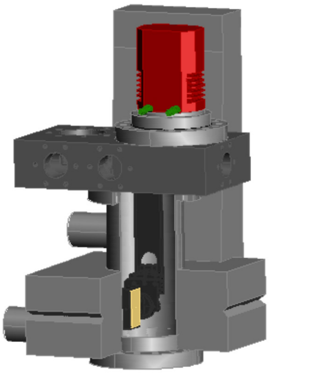


Figure 1: Scheme of the experimental setup for spectroscopic studies on laser induced plasma emission. The components are installed in a high vacuum chamber (except focussing lens). The dashed line denotes the spectrometer.

Setup

In a proof of principle study, a solid target is used to generate a laser plasma and analyse the x-ray radiation. Figure 1 shows the experimental setup: Intense, ultra-short laser pulses are focused onto the surface of an aluminium target leading to ionisation. The light emission from the plasma is characterised by the home-build spectrometer. The device consists of thin metal foil filters to prevent the scattered fundamental laser light, a flat field grating in grazing incidence configuration and the Andor Newton CCD as detector. Due to the high absorption of x-rays under atmospheric conditions the experiment is conducted in a high vacuum environment. Therefore the spectrometer is designed to fit in a DN100CF vacuum manipulator keeping the setup compact. The design allows to adjust both the detector and the grating separately, see figure 2. The flat field grating as dispersive element focuses the x-ray spectrum in a plane matching the chip of the CCD detector. Compared to a monochromator, where the foci are distributed on the Rowland circle, no scanning is necessary and the whole spectrum can be recorded at once. However this feature is paid by weak signal due to the low reflectivity of the grating. Finally, the CCD detector itself is chosen as back illuminated device. So signal losses by absorption of high energy photons are reduced and a high sensitivity in the desired spectral range is provided.



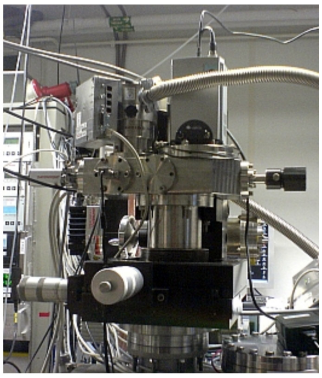


Figure 2: X-ray spectrometer with Newton CCD detector as CAD model (left) and realisation in the lab (right). The CAD model presents the arrangement of CCD detector (red) and grating (yellow) assembled to the vacuum manipulator (grey). With respect to the interaction point, the grating mount (black) offers three degrees of motion decoupled from the detector adjustment by the manipulator.

Results

The x-ray spectrum of an aluminium target irradiated by intense laser pulses has been analysed. Figure 3 (top) shows the spectrally resolved emission of the plasma in the range of 7 nm to 14 nm, recorded with the CCD. The horizontal axis represents the dispersion direction of the grating. Extracting the line spectrum and comparing with the NIST database [2] allows to assign the optical transitions and furthermore to calibrate the dispersion axis, see figure 3 (bottom). Emission from Al IV, Al VI and Al VIII can be identified with a resolution of 70.

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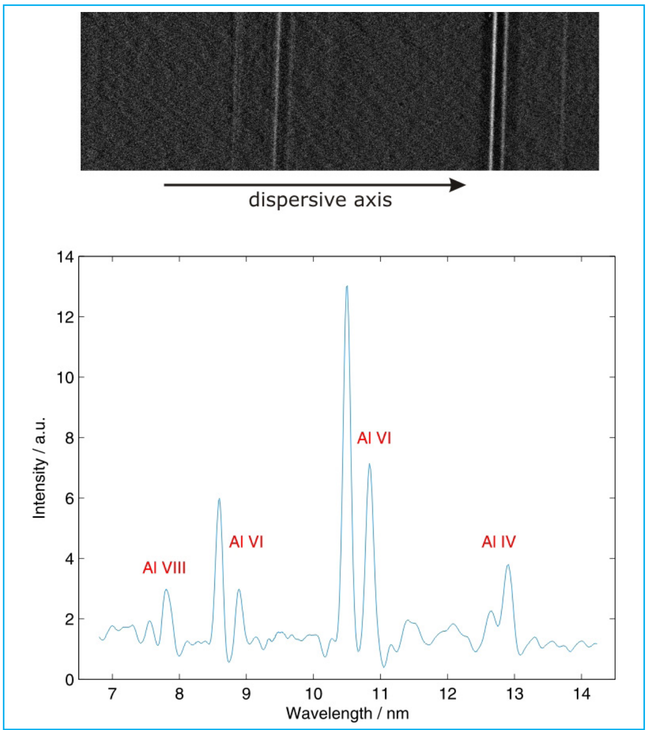

Figure 3: (top) Detailed view of the raw data of the x-ray emission of an aluminium plasma recorded with the Andor Newton CCD. The spectrum has been taken using 50 fs laser pulses with energies of 2 mJ.

(bottom) Extracted line spectrum and assigned optical transitions.

Conclusion

Combining the Newton CCD detector with a flat field grating gives the opportunity to design a compact x-ray spectrometer suitable for basic research. The camera provides convenience in operation under extreme conditions: Besides USB connection and useful software functions, necessary features like vacuum compatibility, chip cooling for dark noise suppression and a back illuminated design allow for weak signal detection.

Application Note

References

[1] Fennel et al., Laser-driven nonlinear cluster dynamics, Rev. Mod. Phys. 82, 1793 (2010)
[2] www.nist.gov

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