

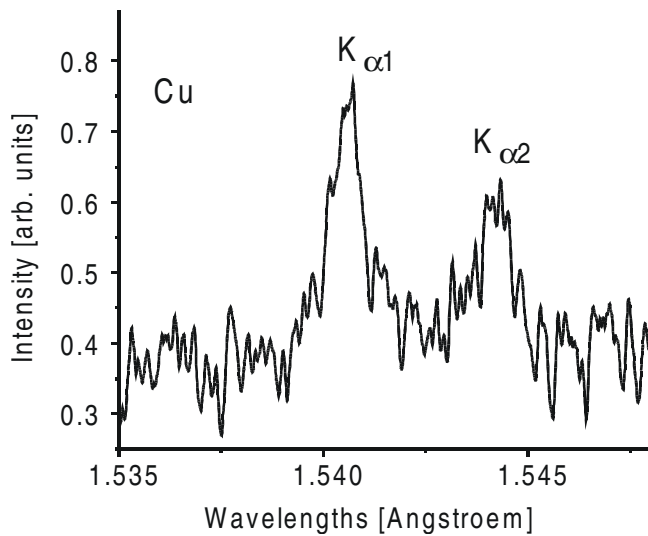
# Implementation of X-Ray Optical Methods for the Investigation of Electron Beam Induced $K_{\alpha}$ -Emission in fs-Laser-Matter Interaction Experiments

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The interaction of high intensity laser pulses with matter leads to the generation of a considerable amount of hot electrons, e.g. [1], [2], [3]. Due to self-generated magnetic fields, electrons return to the target surface and if the hot electron energy exceeds the ionization energy of a target K-shell electron, characteristic  $K_{\alpha}$ -emission is generated, e.g. [4].

In fs-laser matter interaction experiments, the investigation of the spatial formation of the  $K_{\alpha}$ -emission is of great interest because at certain irradiation conditions, a spatial contraction of the x-ray emitting spot [5]. This in turn leads to the possibility for the development of a x-ray source with  $\mu\text{m}$ -dimensions only. The experimental investigation, however, requests simultaneous high spectral resolution (in order to resolve the  $K_{\alpha}$ -doublet) and high spatial resolution (down to  $\mu\text{m}$ -scale).

For these purposes, we have implemented a spherically curved quartz Bragg crystal at the ATLAS fs-laser installation (Ti:Sapphire,  $E = 1.2 \text{ J}$ ,  $\tau = 130 \text{ fs}$ ,  $\nu = 10 \text{ Hz}$ ) at MPQ. The curvature radius was  $R_c = 150 \text{ mm}$ , the lattice spacing  $2d = 4.912 \text{ \AA}$  (provided from MISDC at VNIIFTRI). The maximum theoretical spectral resolution is estimated to be 7000. Spectra were recorded with Kodak DEF 5 x-ray film. X-ray images were processed with a 10.000 dpi (dots per inch) drum scanner (provided from EUROCORE). Crystal and film were covered with a  $9.8 \mu\text{m}$  thick Al and  $10 \mu\text{m}$  thick Ni foil, respectively.



**Figure 1:**  $K_{\alpha}$  emission induced by hot electrons generated by irradiation of a massive copper target with a fs-laser pulse

Massive copper targets were irradiated with intensities up to  $5 \cdot 10^{17} \text{ W/cm}^2$  and about 300 shots were accumulated to obtain x-ray copper ( $Z_n = 29$ )  $K_{\alpha}$ -spectra. A continuously moving target provided a fresh target surface for each shot. Copper  $K_{\alpha}$ -emission near  $1.54 \text{ \AA}$  was recorded in second order ( $n = 2$ ) with a central Bragg angle of  $\Theta = 39.9^\circ$ . The angle between the target normal and the crystal was about  $60^\circ$ . The orientation of the normal of the plane of dispersion (Johann-plane) was

parallel to the target surface: spatial resolution is then provided along the target surface.

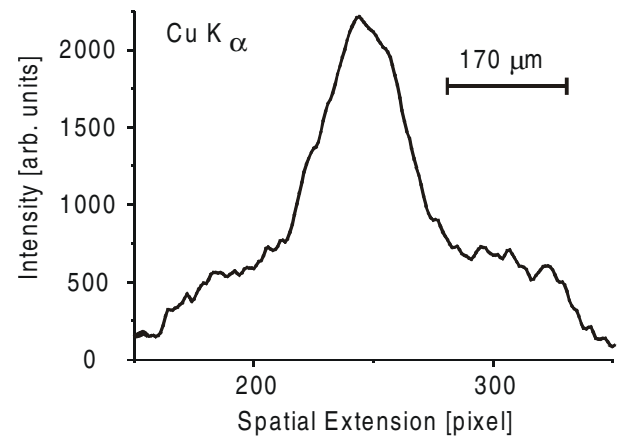
In order to achieve a large spatial resolution (down to  $\mu\text{m}$ -scale) while maintaining high spectral resolution a magnification arrangement which fulfills the conditions of geometrical optics

$$\frac{2 \sin \Theta}{R_c} = \frac{1}{a} + \frac{1}{b}$$

with

$$n \lambda = 2 d_n \sin \Theta$$

was used: the distance between the target and the crystal was  $a=200 \text{ mm}$ , the distance between the crystal and the film was  $b=297 \text{ mm}$ . Figure 1 shows the Cu-  $K_{\alpha}$ -emission near  $8 \text{ keV}$ . Clearly resolved is the  $K_{\alpha}$ -doublet.



**Figure 2:** Spatial extension of the copper  $K_{\alpha}$  emission.

Figure 2 shows the spatial extend of  $K_{\alpha 1}$  (simultaneously obtained with the results of Figure 1) in an experimental series where shots with different laser spot sizes were superimposed. This is clearly reflected by the narrow maximum (about  $150 \mu\text{m}$  FWHM) and a broader plateau (about  $500 \mu\text{m}$ ).

In conclusion we have implemented a two-dimensional curved Bragg-crystal at ATLAS which provides simultaneously high spectral and spatial resolution for the investigation of the spatial extend of the target  $K_{\alpha}$ -emission. It was demonstrated, that even  $8 \text{ keV}$  radiation (from copper  $K_{\alpha}$ ) can be investigated via higher reflection orders of bend quartz crystals.

## References

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