High-brightness liquid-metal-jet-anode electron-impact hard x-ray source

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Abstract
Hard x-ray (multi keV) synchrotron sources with high brightness have enabled novel and important imaging techniques, from x-ray microscopy to medical imaging with improved and new contrast. Unfortunately the brightness of conventional compact hard x-ray sources has not improved significantly since the invention of the rotating anode, making it difficult to envision compact systems for these new imaging modalities based on present sources. In this paper we describe a novel compact electron-impact hard x-ray source with potential for much higher brightness than present state-of-the-art rotating-anode sources. The source can enable improved resolution and contrast in medical imaging and non-destructive evaluation, and has applicability for compact hard x-ray microscopy and certain diffraction applications.

For electron-impact sources the brightness is proportional to the electron-beam power density at the anode. Present rotating-anode and micro-focus technology show little potential for further improvement due to intrinsic thermal limitations. We have introduced a new anode concept, the liquid-metal jet. Calculations show that this new anode allows a 100-1000× increase in source brightness compared to today's compact hard x-ray sources[1],[2]. We presently operate it with a 20-50-µm diameter liquid-tin jet at ~70 m/s with a 50 kV, 600 W electron beam focused to 40-50 µm FWHM. The resulting electron-beam power density is 200-400 kW/mm^2, which is approx 10× higher than on present sources. The emitted spectrum exhibits two tin emission peaks around 25 keV and a broad bremsstrahlung background. Conventional absorption imaging shows excellent spatial resolution (tens of microns). Furthermore, the small source allows phase imaging for improved contrast. Initial results compare well with theoretical modelling.

This paper will describe the source system properties as well as show early high-resolution imaging results, with and without phase effects. We will also discuss the source's extension to lower (10 keV) and higher (>50 keV) energies. Finally, we will elaborate on the new source's applicability for hard x-ray microscopy and medical imaging.

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[1] O. Hemberg, M. Otendal, and H. M. Hertz, Appl. Phys. Lett. **83**, 1483 (2003).
[2] O. Hemberg, M. Otendal, and H. M. Hertz, Opt. Engin. **43**, 1682 (2004).