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Sources and Blankers for Ultra-Fast Electron Microscopy

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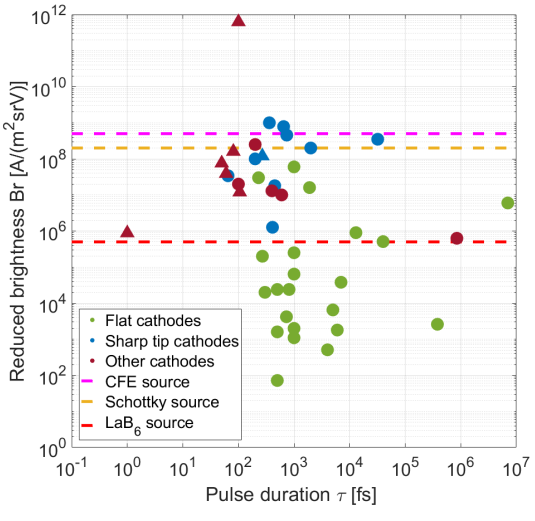
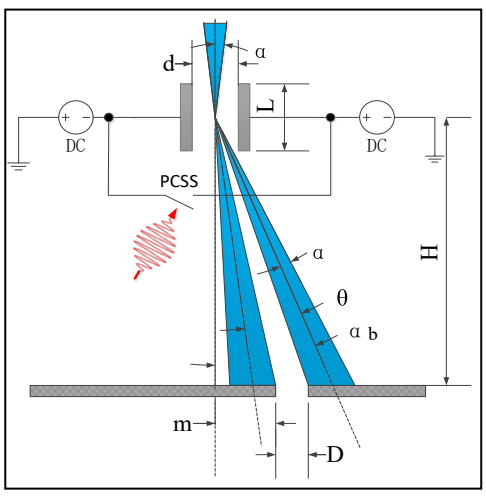
Ultrafast electron microscopy (UEM) is a technique to observe dynamic phenomena at both high spatial and temporal resolution [1]. The scales that can ultimately be achieved depend on the quality of the generated electron pulses. The most important quality parameter is the brightness, because this determines how many electrons are available within a certain time on a certain area of the sample. We have analysed, to the best of our knowledge, all photoemission sources and beam blankers reported to date to generate ultrashort pulses and compared their brightness [2]. We conclude that state-of-the-art photo-emission sources for UEM operate at brightness values close to that of continuous sources, while beam blankers do that almost by definition, see figure 1. We also see that beam blankers can give the same pulse duration as photo-emission sources but are used far less frequently. Beam blanking is a scheme where the electron beam is deflected over an aperture by a changing field between two plates.
One approach to fast beam blanking is to use microwave cavities, which require an extension of the microscope column [3], but are furthest advanced in their development. We are trying to design a fast beam blanker of such small dimensions that it can be integrated into an aperture holder stick of an electron microscope, so it could be added to any existing microscope. By traditional techniques, we managed to reach sub-100 ps pulses [4], but we would like to go sub-1 ps. We know that 7 ps pulses have been produced by optimized design [5], but we are trying a new direction.
A first design was presented by Weppelman et.al [6]. This design consisted of a micro-fabricated assembly of an integrated photo-conductive switch and a beam deflector. An advantage of using a photo-conductive switch is that the electron pulses are automatically synchronized to the laser pulses used for sample pumping, like in the case of photoelectron guns. However, microfabrication of a photo-conductive switch and a beam deflector in one device as tried by Weppelman is difficult. Simpler designs may be possible if we separate the photo-switch and the deflector, but we may need to accept slightly longer pulses. We are now trying to use a commercial LT-GaAs photo conductive switch to rapidly discharge the blanker plates, thereby deflecting the electron beam (see figure 2).

References

[1] Zewail, Science 328 (2010), p. 187
[2] Zhang et al., Ultramicroscopy 211 (2020), p. 112925
[3] Lassise et al., Rev. Sci. Instr. 83 (2012) p. 43705
[4] Moerland et al., Optics Express 24 (2016) , p. 24760
[5] Winkler et al., Microelectronic Engineering 11 (1990), p. 657
[6] Weppelman et al., Ultramicroscopy 184 (2017), p. 8



← Fig.1: Brightness of all reported sources for Ultra-fast Electron Microscopy.



➔ Fig 2.: Schematic of photo-switched blanker