Electron Mirror Pulse Compression for Ultrafast Electron Diffraction and Dynamic Electron Microscopy

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Many dynamical processes at the atomic scale occur on timescales as short as tens to hundreds of femtoseconds. Pulsed laser techniques have the requisite temporal resolution, but not the spatial resolution to follow these processes. Pulsed electron techniques have recently been developed [1] to address such problems. In Ultrafast electron diffraction (UED) and Dynamic transmission electron microscopy (DTEM) an unprecedented combination of spatial and temporal resolution is obtained by illuminating a photocathode with an ultrafast pulsed laser, accelerating the photoemitted electrons and illuminating a specimen with the ultrafast electron pulse to obtain time-resolved electron diffraction patterns or images. Unfortunately, Coulomb interactions broaden the pulse as the electrons travel from the photocathode to the sample, resulting in a loss of temporal resolution when the pulse arrives at the specimen. In spite the significant efforts that have been made to shorten these ultrafast electron pulses, there is strong demand to further improve the temporal resolution of the probing pulse to reach into the femtosecond range without sacrificing total bunch charge. We propose to develop a novel electron pulse compressor (Fig. 1) that can compress a linearly velocity-chirped electron pulse at the specimen into the sub-100 femtosecond range. The pulse compressor utilizes an electrostatic electron mirror combined with a beam separator composed of a magnetic prism array that allows normal beam entrance to minimize mirror aberrations. After reflection in the mirror, the velocity distribution of the pulse is inverted, as the trailing edge of the pulse has a higher energy than the leading edge. The inversion of the velocity distribution results in the temporal compression of the propagating pulse once the pulse is allowed to drift to the specimen. The mirror can be tuned to accommodate pulses with a varying number of electrons and can be adapted to UED and DTEM columns of different lengths. The combination of the beam separator with the electron mirror allows the axis from the gun to the specimen to remain straight, which simplifies alignment and minimizes aberrations. Furthermore, the static nature of the electron mirror simplifies set-up and tuning of the pulse compressor and thus avoids the jitter problem associated with RF pulse compression techniques [2].

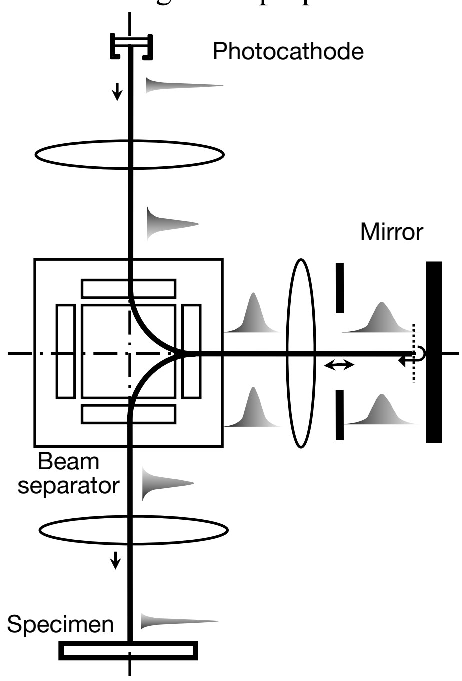

Figure 1. Pulse compressor principle.

References
[1] R. J. Dwayne Miller, Science Vol. 343 (2014), pp. 1108-1116.
[2] R. Chatelain et al., *Appl. Phys. Lett.* Vol. 101 (2012), p. 081901.