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Ultrafast TEM and EELS Based on Microwave Cavities

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Ultrafast Transmission Electron Microscopy (U-TEM) has become a very important tool for the study of ultrafast phenomena at (sub-)nm length scales and (sub-)ps time scales. U-TEM is usually based on the creation of ultrashort electron pulses by femtosecond laser photoemission from a flat cathode, with the result that both the beam quality and the average current are significantly less than in state-of-the-art continuous-beam TEMs. At Eindhoven University we have developed U-TEM in which ultrashort electron pulses are produced by using a 3 GHz deflecting cavity in TM_{110} mode, synchronized to a femtosecond laser, to sweep a high-brightnes continuous beam across a slit. In this way the beam quality and the sub-eV energy spread of the FEG source of an adapted 200 keV Tecnai TEM are conserved, enabling near-atomic spatial resolution with sub-ps temporal resolution [1]. First results of pump-probe experiments will be presented.

In addition we have developed a new method for doing Time-of-Flight Electron Energy Loss Spectroscopy (ToF-EELS) based on the combined use of two TM_{110} deflecting cavities and two TM_{010} (de)compression cavities. The first 'chopping' TM_{110} cavity produces ultrashort electron pulses which are sent through a sample. Energy loss in the sample translates into reduction of the electron velocity and thus into a later arrival time at the detector, which is measured with a synchronized second TM_{110} 'streak' cavity. In this way an energy resolution of 12 eV at 30 keV has been demonstrated [2]. By adding a TM_{010} cavity in compression mode *after* the sample, the longitudinal phase space can be manipulated in such a way that the energy resolution is improved to 2 eV [3]. By adding a second TM_{010} cavity in stretching mode *before* the sample, the electron pulses can be monochromated without loss of current. Detailed charged particle tracking simulations show that an energy resolution of 20 meV combined with a temporal resolution of 2 ps can then be achieved. The 4-cavity ToF-EELS setup is currently under construction and first results will presented.

References

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