Developing new methods to tailor the phase-space distribution of electron beams is both a challenging and essential endeavor, constituting the cornerstone of recent advancements in ultrafast electron microscopy. At TU/Eindhoven, we utilize a miniaturized RF-cavity in TM110 mode to chop the continuous beam of a conventional transmission electron microscope into ultrashort pulses. This approach has led to the development of an RF-cavity-based ultrafast transmission electron microscope (UTEM) [1], capable of generating few-100-fs pulses with GHz-MHz repetition rates while preserving the low emittance (~2 pm rad) and energy spread (< 1 eV) of the TEM Schottky field emission gun (FEG).

Integration of a 75 MHz laser oscillator into our UTEM setup allows for the observation of synchronized in-vacuum interactions between free electrons and fs-laser pulses for novel free-electron quantum optics. We have devised techniques to coherently shape the electron wavefunction amplitude and phase through a combination of elastic and inelastic light-electron scattering [2]. These interactions are harnessed in photon-induced near-field electron microscopy and dynamic ponderomotive phase shaping experiments, with the ultimate objective of developing pulsed laser-based Zernike phase plate imaging at high repetition rates [3].

The generation of highly degenerate free-electron beams for next-generation TEMs, characterized by strong anti-correlation governed by the Pauli exclusion principle, is garnering increasing attention in the scientific community. In this context, we have developed a method to measure the arrival time of individual electrons with femtosecond-level resolution, serving as a crucial diagnostic tool for the development of degenerate free-electron quantum sources. Using this method, we have observed an increasingly pronounced sub-Poissonian behavior in the arrival time of the free electrons within the continuous beam generated by the TEM FEG as the observation time window was reduced from 2 ps to few-100-femtoseconds [4].

In this contribution we present an overview of our recent progresses.

References:

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