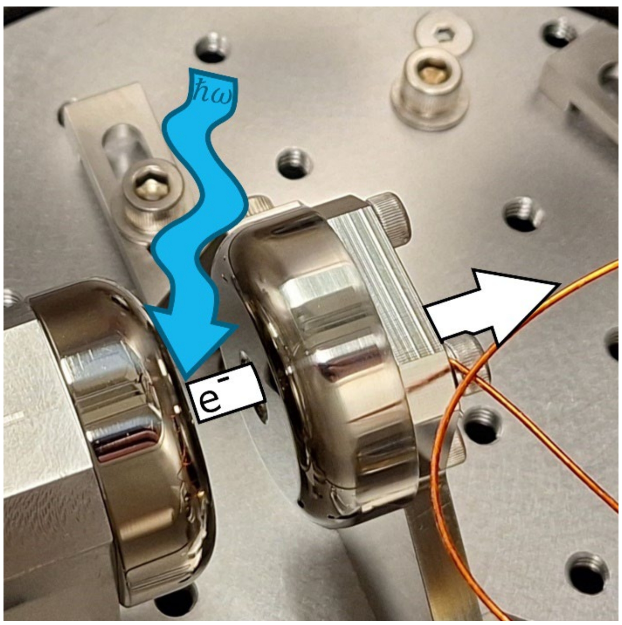
Photocathode characterization using a UV-tunable ultrashort pulse radiation source

W. Andreas Schroeder

Department of Physics, University of Illinois – Chicago

Accurate experimental spectral characterization of the electron emission properties of solid-state materials is a key component in the search for new high brightness photocathodes; an improved understanding of the experimental data through theoretical photoemission models allowing for more refined and targeted searches of the vast catalog of known materials [*Advanced Materials* **33**, 2104081 (2021)]. The photocathode characterization system at the University of Illinois – Chicago with its large 3.0-5.3eV near-UV spectral coverage is just one example of the type of equipment required to measure the spectral dependence of both the quantum efficiency (QE) and mean transverse energy (MTE) of photoemitted electrons. This presentation will describe the design considerations for our experimental system; including the reasons for the use of (i) a laser-based, high repetition rate (10-100MHz), sub-picosecond radiation source, (ii) a 10-20kV DC gun (pictured) followed by a ~40cm drift region, (iii) Fourier spatial filtering of the 60º incident *p*-polarized UV radiation, (iv) a micro-channel plate (MCP) electron detector with a P43 phosphor screen, and (v) a low noise CMOS digital camera. The resulting system is capable of measuring MTE values well below 5meV and QE values down to ~10^{-10}.



The photocathode characterization system is calibrated using a Rh(110) photocathode for which the measured spectral dependences of the QE and MTE are known to be consistent with a band-based photoemission simulation [*AIP Advances* **9**, 065305 (2019)]. An integral aspect of this calibration (and other measurements) is the determination of the work function, using the theoretical spectral dependence of the QE, as it sets the excess photoemission energy for the MTE. Hence, all spectral characterization measurements are generally performed after exposing the photocathode surface to ~1W/cm^2 of 257nm UV radiation for 20-30 minutes. Monitoring of both the QE and MTE as a function of UV exposure time during this 'laser cleaning' process indicates that the dominant effect is a reduction in the surface work function. For single-crystal metal photocathodes, the UV laser cleaning typically reduces the work function by 0.2-0.5eV, resulting in values that are in better agreement with 'perfect crystal' calculations based on density functional theory (DFT).