Near-Threshold Nonlinear Photoemission from Cu(100)

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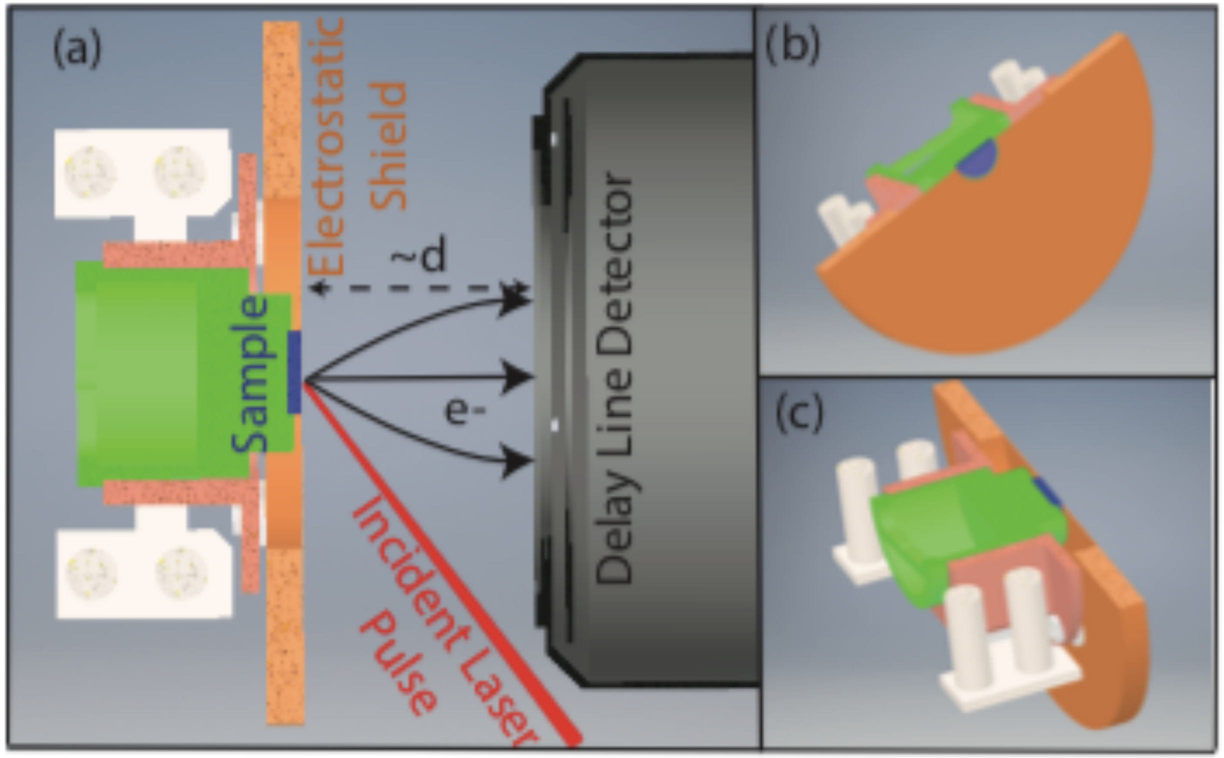
Introduction

- Photocathodes that have a low mean transverse energy (MTE) are crucial to the development of compact X-ray Free Electron Lasers and ultrafast electron diffraction experiments
- MTE dependent upon excess energy [1], band structure of photocathode [2], nonlinear photoemission effects [3,4]
- Here we present measurements of nonlinear photoemission near threshold on Cu(100)
- We extrapolate our data to gain insight into the affects of nonlinear photoemission on the MTE at a wavelength and fluences typically used in photoinjectors.

Experimental Setup

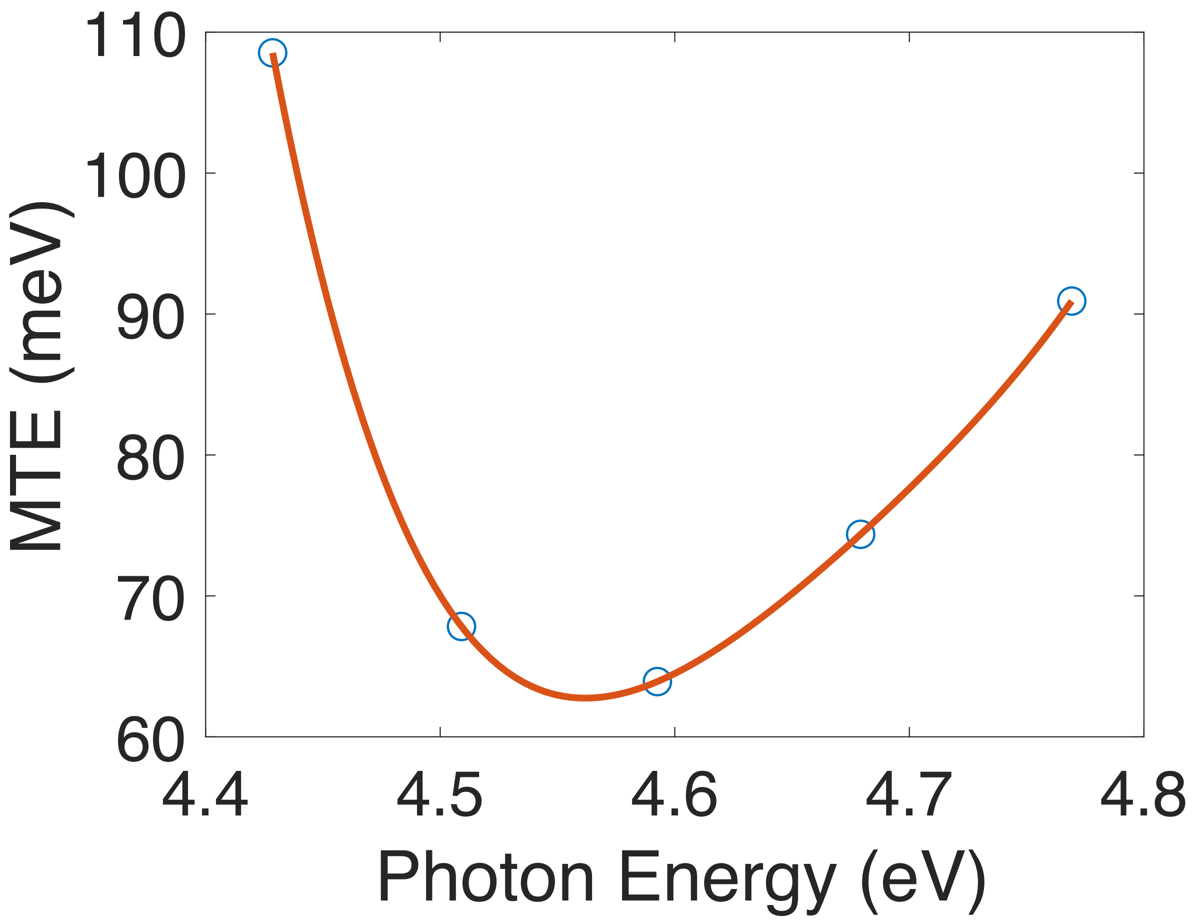
- Performed under UHV (low 10^{-10} Torr)
- Cu(100) sample annealed without ion bombardment
- Femtosecond pulsed laser operating at 500 kHz
- Tunable wavelength optical parametric amplifier
- 150 fs +/- 50 fs laser focused down to 40 μm
- TOF based energy analyzer [5]
  - Measures x and y position and TOF of emitted electrons
- ND filters used to change fluence



S.Karkare *et al*, Rev. Sci. Instrum. 90 053902 (2019)

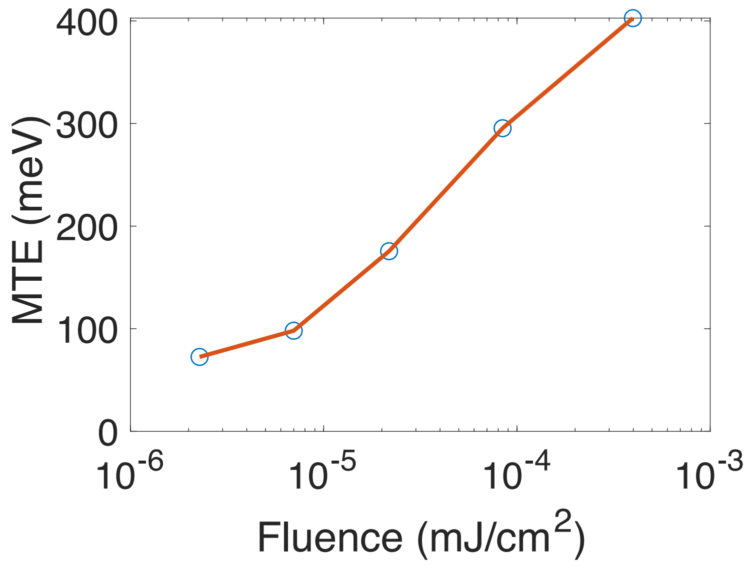
Results

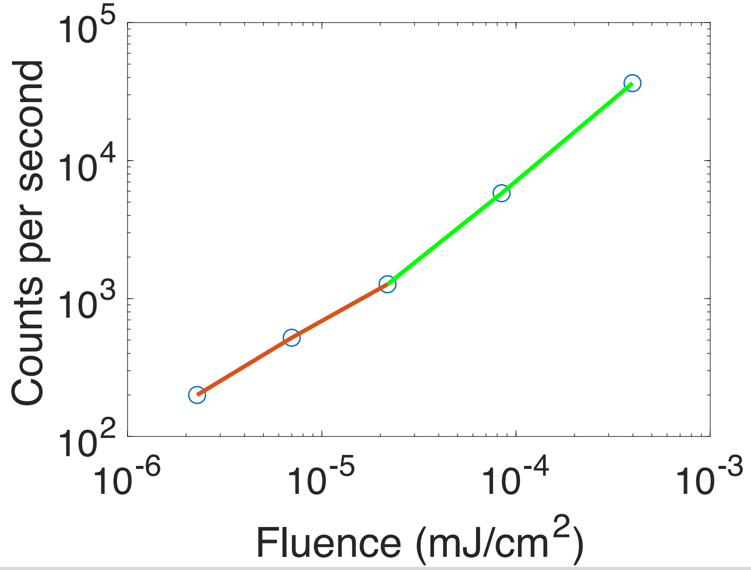
- Data collected for 260 nm – 290 nm
- Measured work function of 4.56 eV
  - Good agreement with known value of 4.59 eV [5]
- MTE vs photon energy plotted for 10^{-7} mJ/cm^2
- Minimum MTE approximately coincides with measured work function
  - Good agreement with theory[3]



Results for 280 nm

- 280 nm photoemission investigated at various powers
- Want to see how below threshold nonlinear effects change with power
- Low fluences, single photon emission from fermi tail
- High fluences, multiphoton emission





Extrapolation

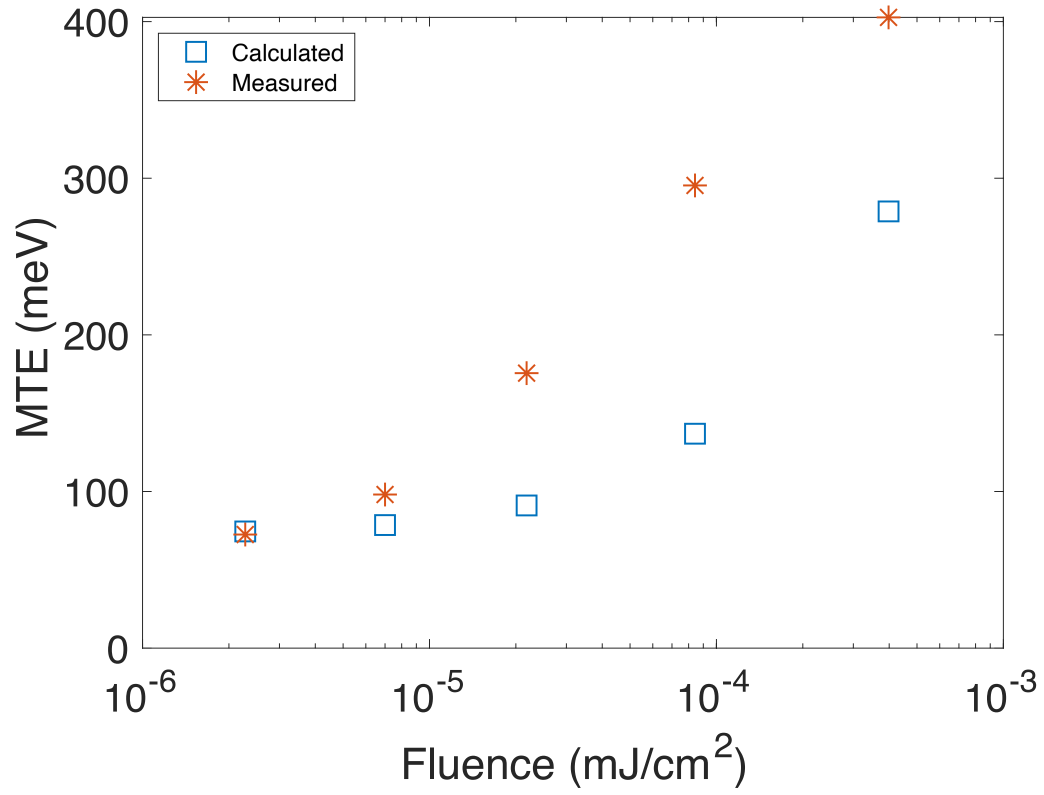
- Want to explore 265 nm in 0.1 mJ/cm^2 to 3 mJ/cm^2 range
- $MTE = \frac{1}{N}\left(\frac{N_l \cdot MTE_l}{\frac{F_l}{F}} + \frac{N_{nl} \cdot MTE_{nl}}{\left(\frac{F_{nl}}{F}\right)^2}\right)$
- Where:
  - $N = \frac{N_l}{\frac{F_l}{F}} + \frac{N_{nl}}{\left(\frac{F_{nl}}{F}\right)^2}$
  - N_l: Electron counts per second
  - F_l: Fluence (mJ/cm^2)
  - MTE_l: MTE (meV)
  - Subscripts
    - l:Linear component
    - nl: Nonlinear component

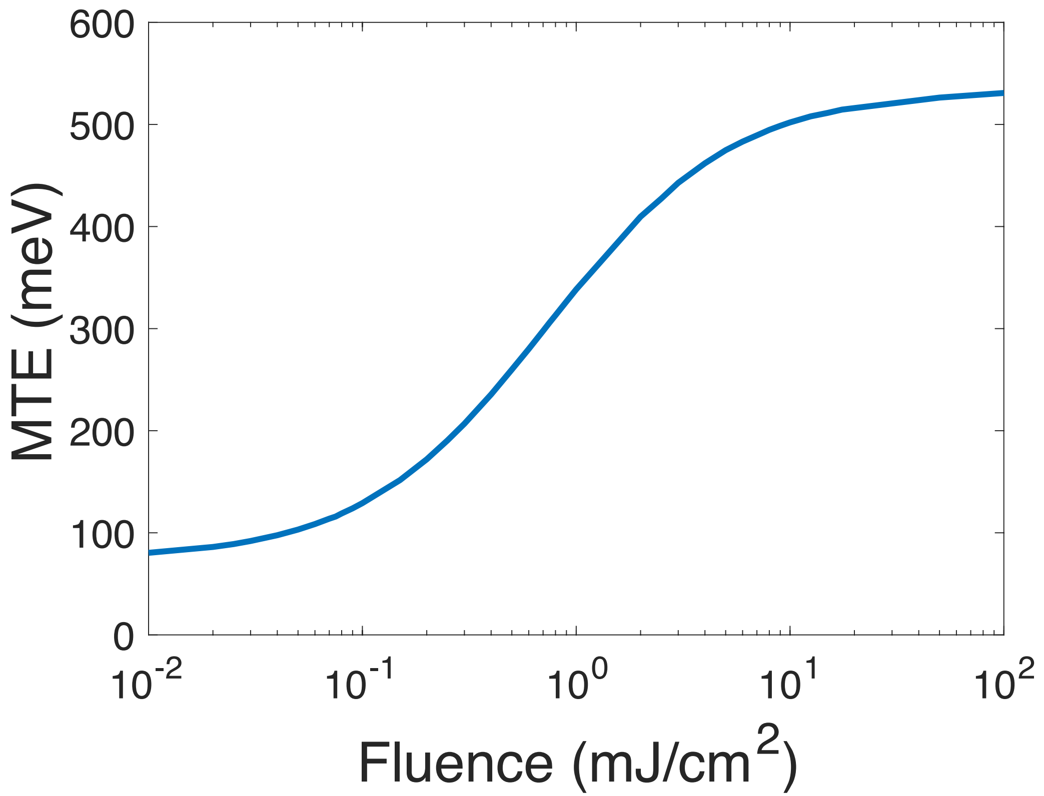
λ(nm)	Count/sec	MTE (mev)	Fluence (mJ/cm^2)
265	46500 (N_l)	74 (MTE_l)	3.82 x 10^{-7} (F_l)
280	200 (N_l)	72.52 (MTE_l)	2.28 x 10^{-6} (F_l)
290	52300 (N_{nl})	533 (MTE_{nl})	5.63 x 10^{-4} (F_{nl})

Extrapolation Continued

- Accuracy checked for 280 nm
- Provides lower limit

- Applied to 265 nm
- MTE increases by factor of 3-4 in 0.1 mJ/cm^2 to 3 mJ/cm^2 range





Conclusions/Future Work

Conclusions

- MTE increases significantly near threshold due to nonlinear effects
- Extrapolated data to see that MTE increases by a factor of 3 to 4 at 265 nm and 0.1 mJ/cm^2 to 3 mJ/cm^2

Future Work

- Look at same effects with pristine atomically clean Cu(100)
- Perform experiments with laser pulses of ~ 10 ps in length which are more often used in photoinjectors

Acknowledgements

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References

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