Near-Threshold Nonlinear Photoemission from Cu(100)

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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 is 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.
• 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

• 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]
• 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
• Want to explore 265 nm in 0.1 mJ/cm² to 3 mJ/cm² range

\[ MTE = \frac{1}{N} \left( \frac{N_l \cdot MTE_l}{F_l} + \frac{N_{nl} \cdot MTE_{nl}}{(F_{nl})^2} \right) \]

• Where:
  - \( N = \frac{N_l}{F_l} + \frac{N_{nl}}{(F_{nl})^2} \)
  - \( N_l \): Electron counts per second
  - \( F_l \): Fluence (mJ/cm²)
  - \( MTE_l \): MTE (meV)

Subscripts
  - \( l \): Linear component
  - \( nl \): Nonlinear component

<table>
<thead>
<tr>
<th>( \lambda (\text{nm}) )</th>
<th>Count/sec</th>
<th>MTE (meV)</th>
<th>Fluence (mJ/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>265</td>
<td>46500 ((N_l))</td>
<td>74 ((MTE_l))</td>
<td>3.82 \times 10^{-7} ((F_l))</td>
</tr>
<tr>
<td>280</td>
<td>200 ((N_l))</td>
<td>72.52 ((MTE_l))</td>
<td>2.28 \times 10^{-6} ((F_l))</td>
</tr>
<tr>
<td>290</td>
<td>52300 ((N_{nl}))</td>
<td>533 ((MTE_{nl}))</td>
<td>5.63 \times 10^{-4} ((F_{nl}))</td>
</tr>
</tbody>
</table>
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/cm² to 3 mJ/cm² range

![Graph 1](image1)

![Graph 2](image2)
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/cm² to 3 mJ/cm²

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


