LA-UR-18-27723

Title: Studies of the field assisted photoemission from nanocrystalline diamond and diamond field emitter arrays

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Intended for: Advanced Accelerator Concepts, 2018-08-12/2018-08-17 (Breckenridge, Colorado, United States)

Issued: 2018-08-13

STUDIES OF THE FIELD ASSISTED PHOTOEMISSION FROM NANOCRYSTALLINE DIAMOND AND DIAMOND FIELD EMITTER ARRAYS

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AAC2018

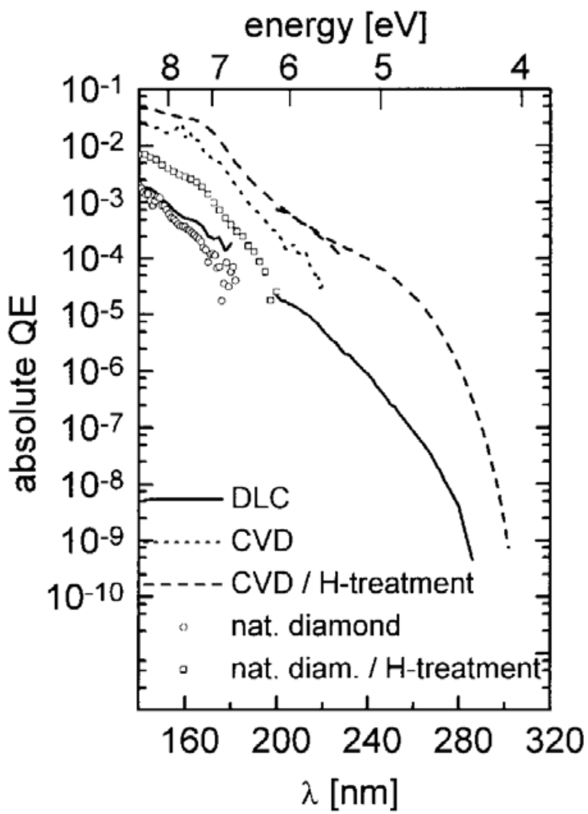
August 15th, 2018

What type of electron source is needed for dielectric laser accelerators?

Field emission in DFEAs	Photoemission
• **0.1 mA per 10 μm square** • **100 A/cm^2**	• UV laser 193 nm (6.4 eV), 200 mJ/pulse (20 ns). • Focus down to 5 mm x 5 mm. • 40 W in 10μm x 10μm (4*10^{19} photons/s). • With QE ~10^{-3} we get 4*10^{16} electrons/emitting surface/s, or • **3 mA per 10 μm square** • **3*10^3 A/cm^2**

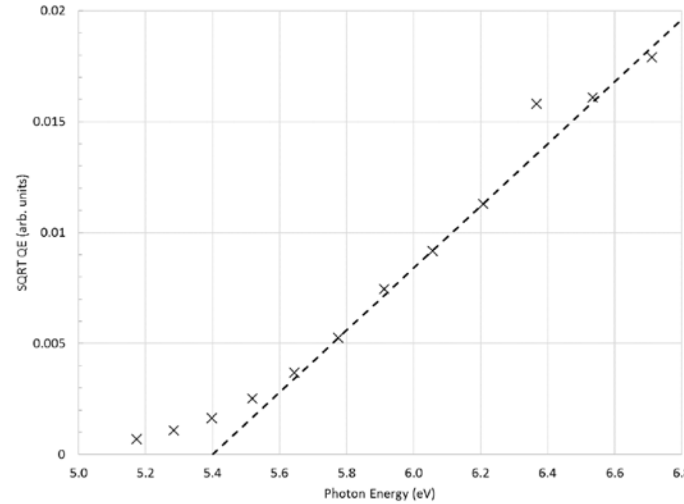
Small and well defined emission spot
High current
Photo-gated source

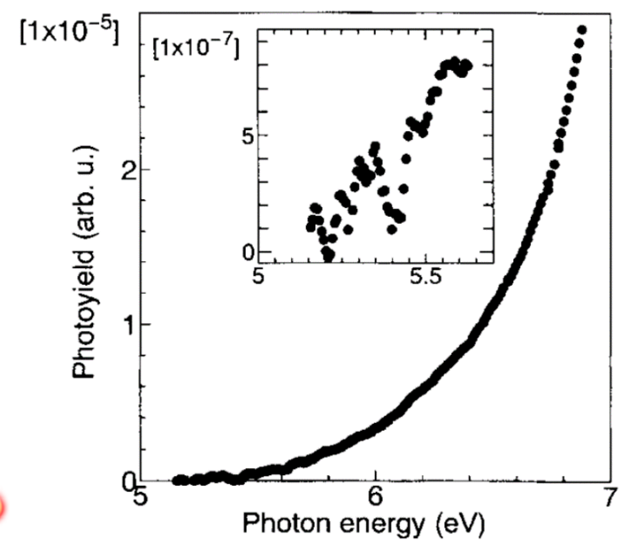
Photoemission from flat diamond: our data in agreement with existing reports



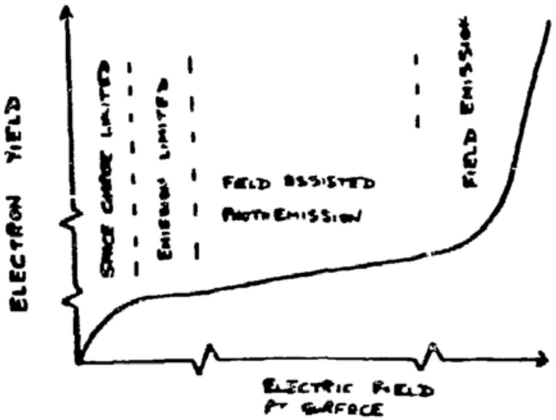
A. Breskin, R. Chechik, E. Shefer, *et al*., Appl. Phys. Lett. **70** (1997) 3446

N. Eimori, Y. Mori, A. Hatta, T. Ito, A. Hiraki, Diamond & Related Materials **4** (1995) 806



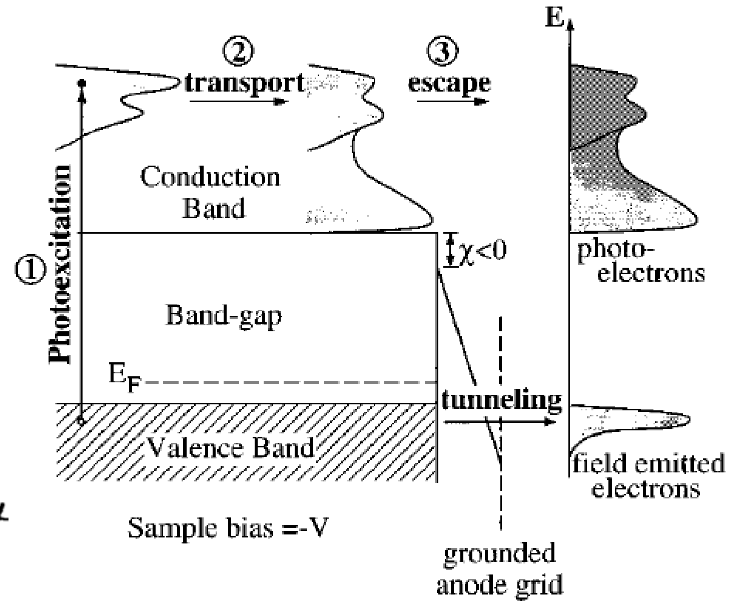


From Photoemission to Field Emission

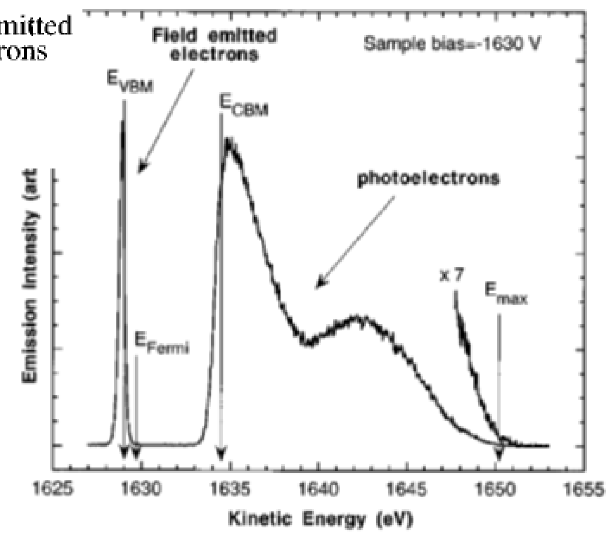


SCHEMATIC VIEW OF FIELD EFFECTS ON PHOTOEMISSION FOR CONSTANT LIGHT ENERGY

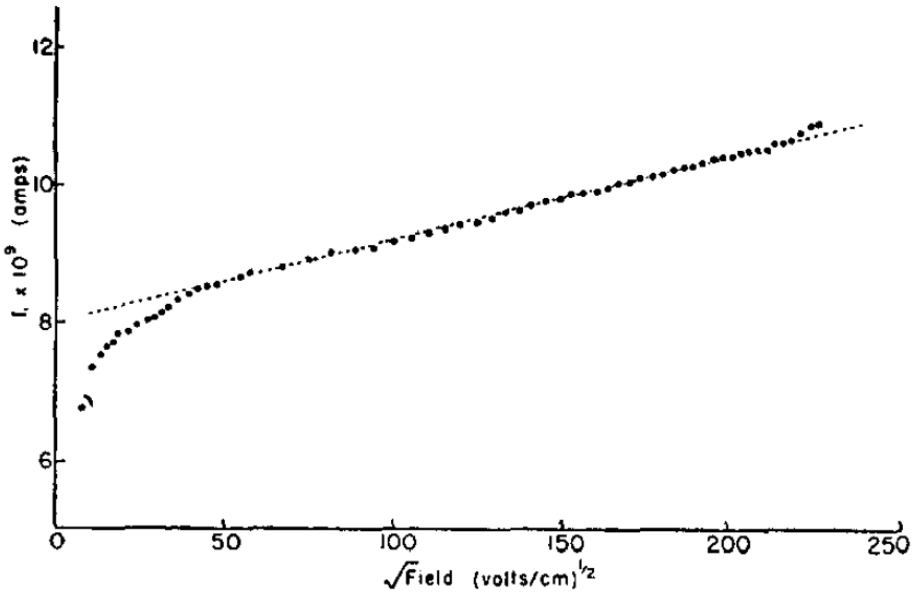
J. Fischer and T. Srinivasan-Rao, UV PHOTOEMISSION STUDIES OF METAL PHOTOCATHODES FOR PARTICLE ACCELERATORS, Fourth Workshop on Pulse Power Techniques for Future Accelerators, E. Maiorana Center, Erice, Italy, March 1988



C. Bandis and B. B. Pate, Simultaneous field emission and photoemission from diamond, Appl. Phys. Lett. **69** (3), 1996

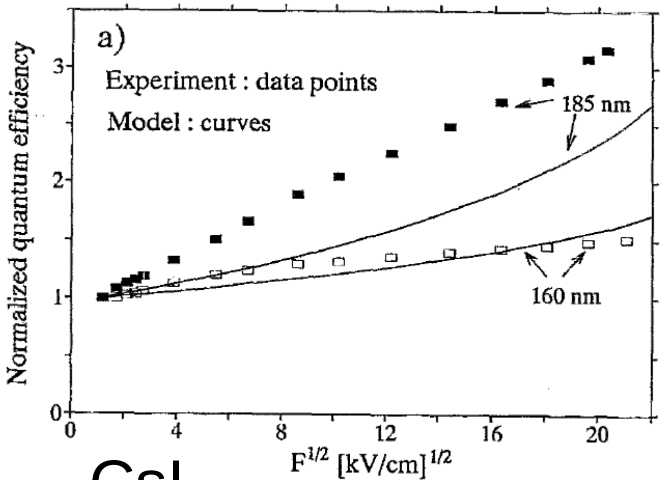


Field Assisted Photoemission: Metals & Semiconductors



Photoelectric Schottky effect for polycrystalline tantalum

D. W. Juenker, Journal of Applied Physics **28** (1957) 1398



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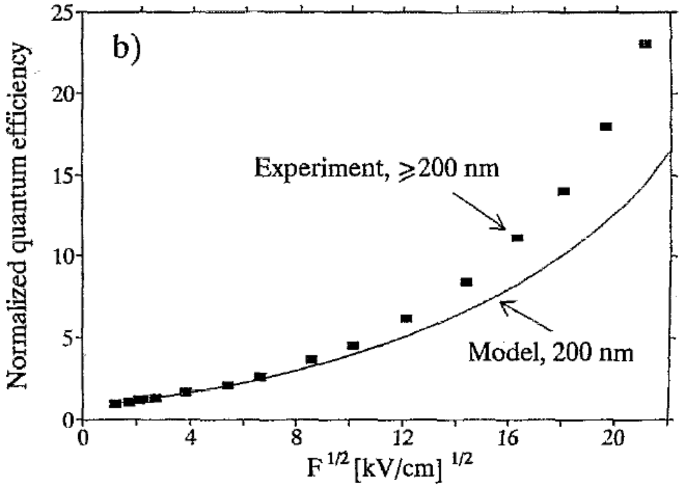

A. Buzulutskov, A. Breskin, and R. Chechik, Journal of Applied Physics **77**, 2138 (1995)

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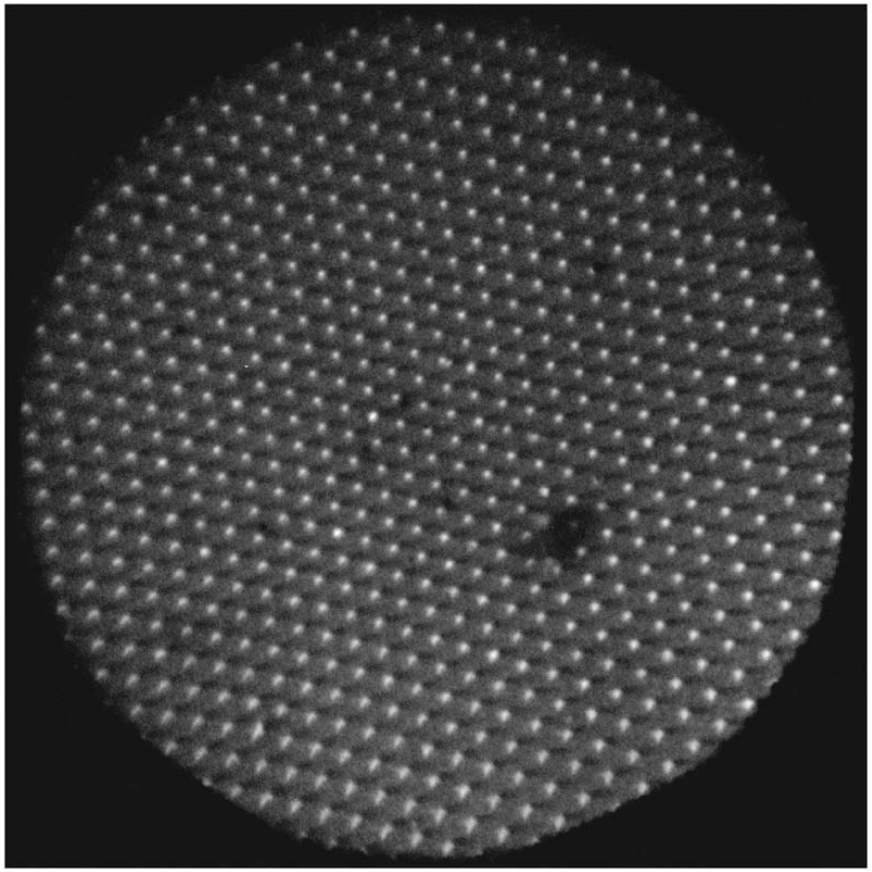
LDRD innovation for our nation

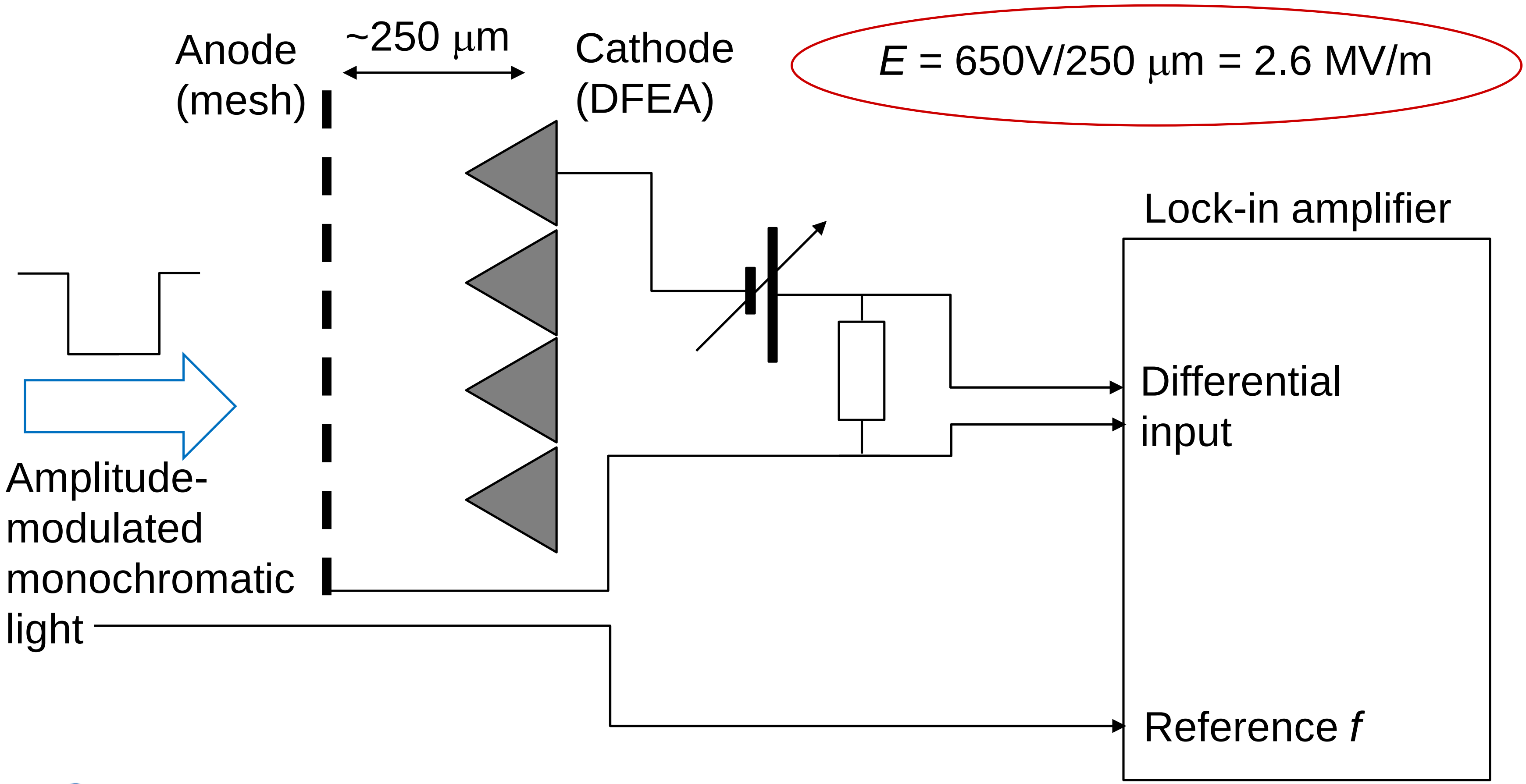
Field Assisted Photoemission from DFEA: existing studies



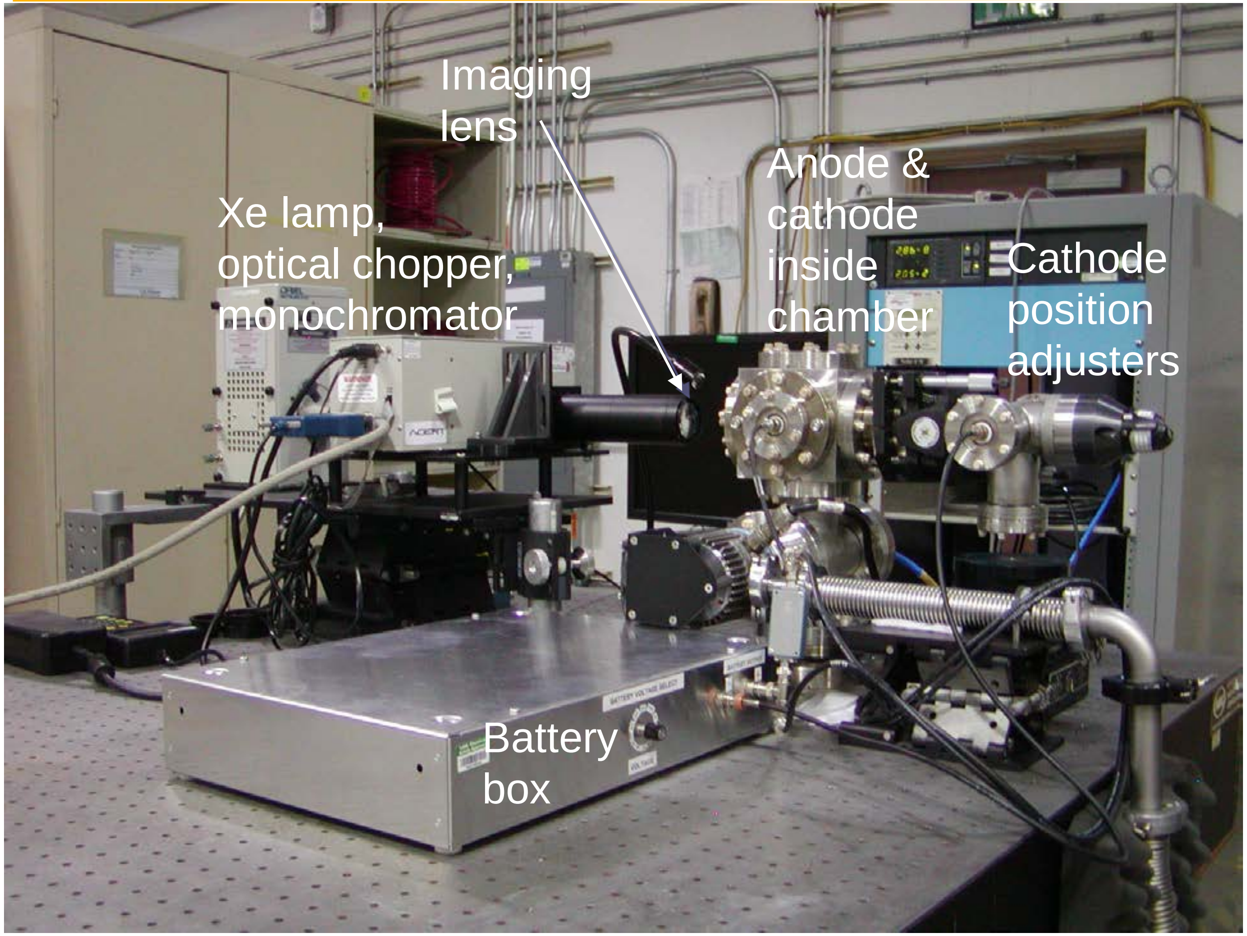
A PEEM image of the UNCD coated tip array at room temperature. Emission is evident from both the flat areas of the sample and the tipped structures.

J. M. Garguilo *et al*., Thermionic field emission from nanocrystalline diamond-coated silicon tip arrays, Phys Rev B **72**, 165404 (2005)

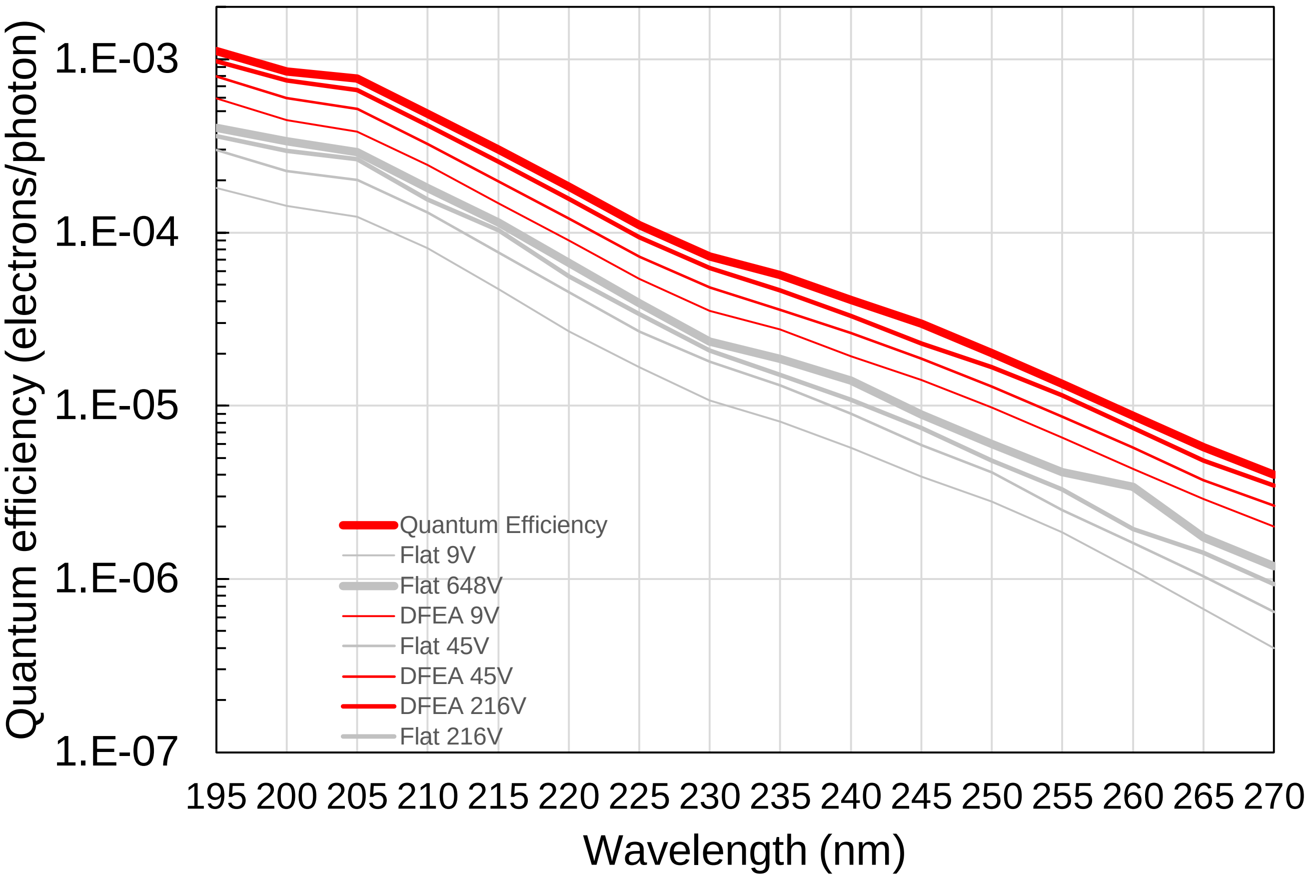
QE measurements scheme in electric fields up to ~3 MV/m

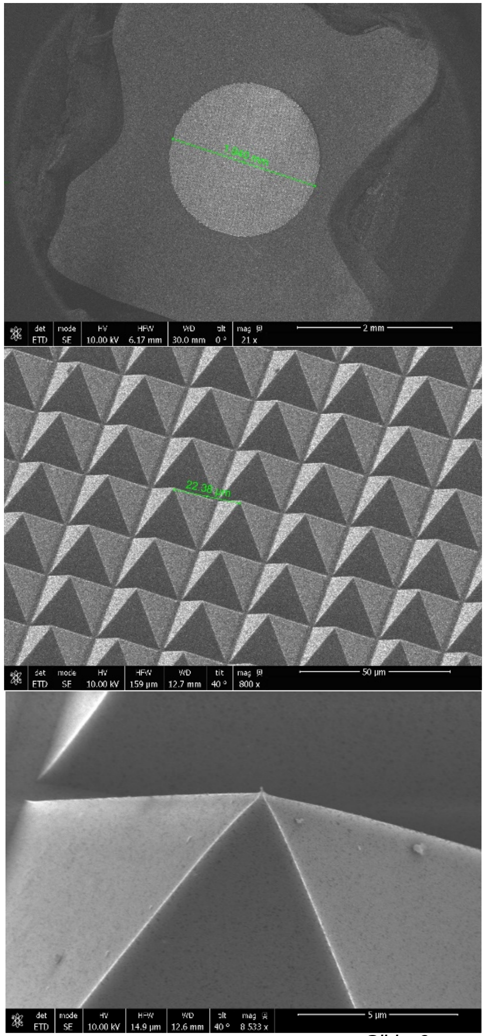


Field assisted photoemission setup

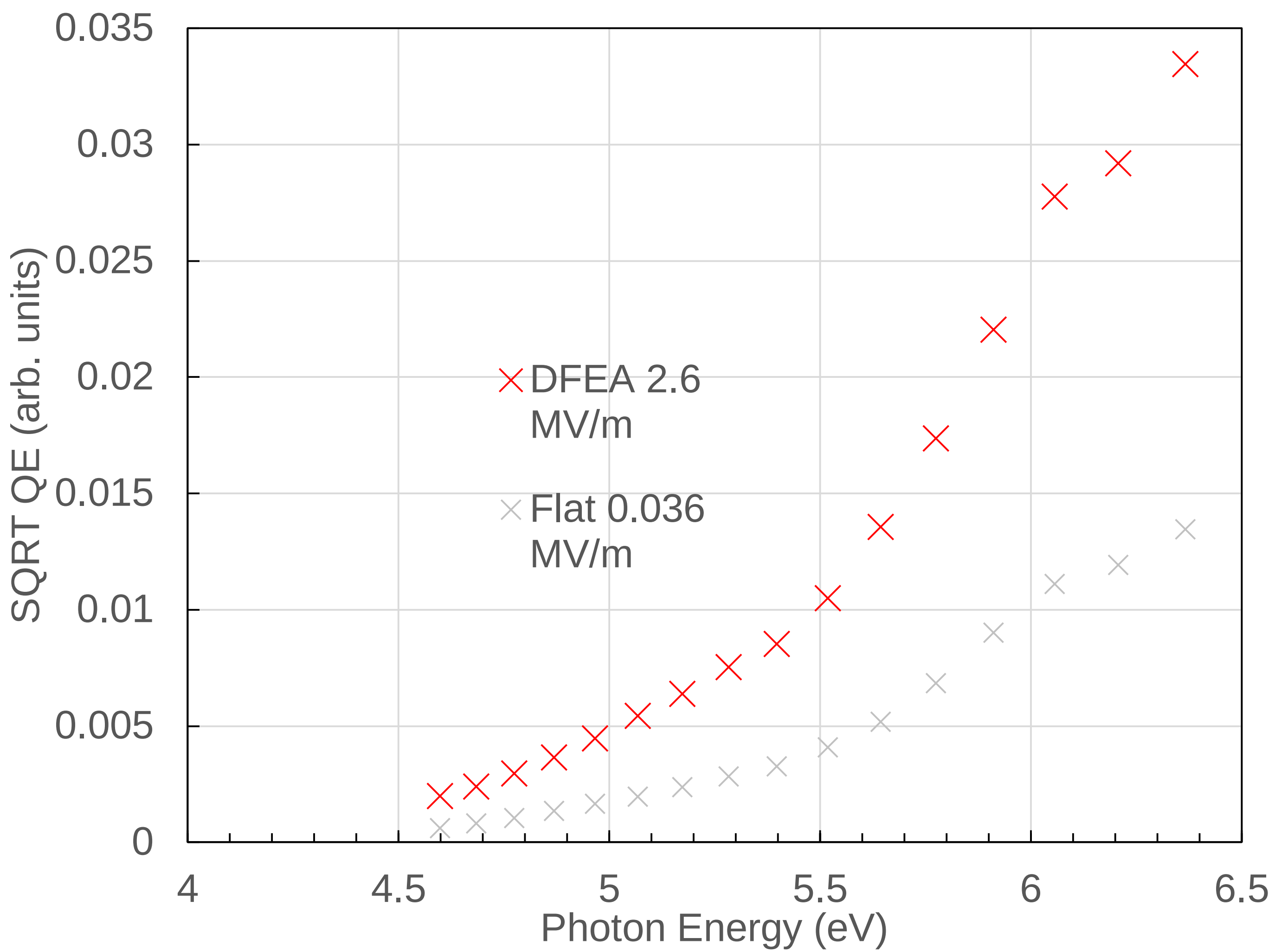


Measurements results: spectral response





Measurements results: photoemission threshold



Conclusions / Future Plans

- Experimental results indicate enhanced photoemission from relatively dense DFEAs, as compared to flat nanocrystalline diamond
- x3 enhancement of photoemission QE near the threshold in electric fields ~1 MV/m is observed in both flat and DFEA-patterned diamond samples, but the mechanism of enhancement is unclear
- Photoexcitation of individual tips with focused laser light is the next step to obtain quantitative QE data in high electric fields

Acknowledgements

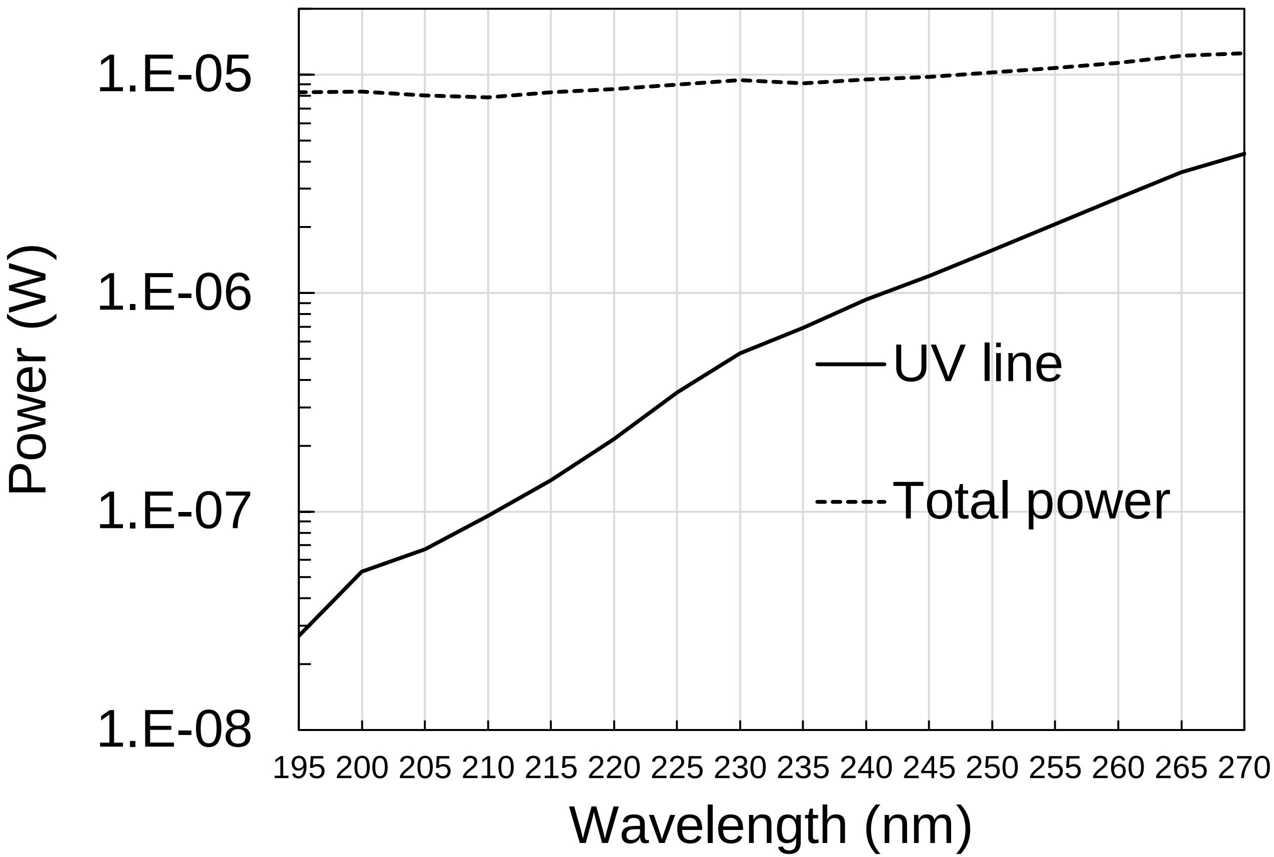
The authors gratefully acknowledge the support of the U.S. Department of Energy through the LANL/LDRD Program for this work. This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy (DOE) Office of Science by Los Alamos National Laboratory (Contract DE-AC52-06NA25396) and Sandia National Laboratories (Contract DE-NA-0003525). We are thankful to:

- Bo Choi: low noise current measurements
- Fangze Liu: experiment automation
- Sergey Baryshev and Sergey Antipov of Euclid Techlabs LLC: (N)UNCD samples and valuable discussions
- Mark Hoffbauer: precision mechanics

Related Presentations

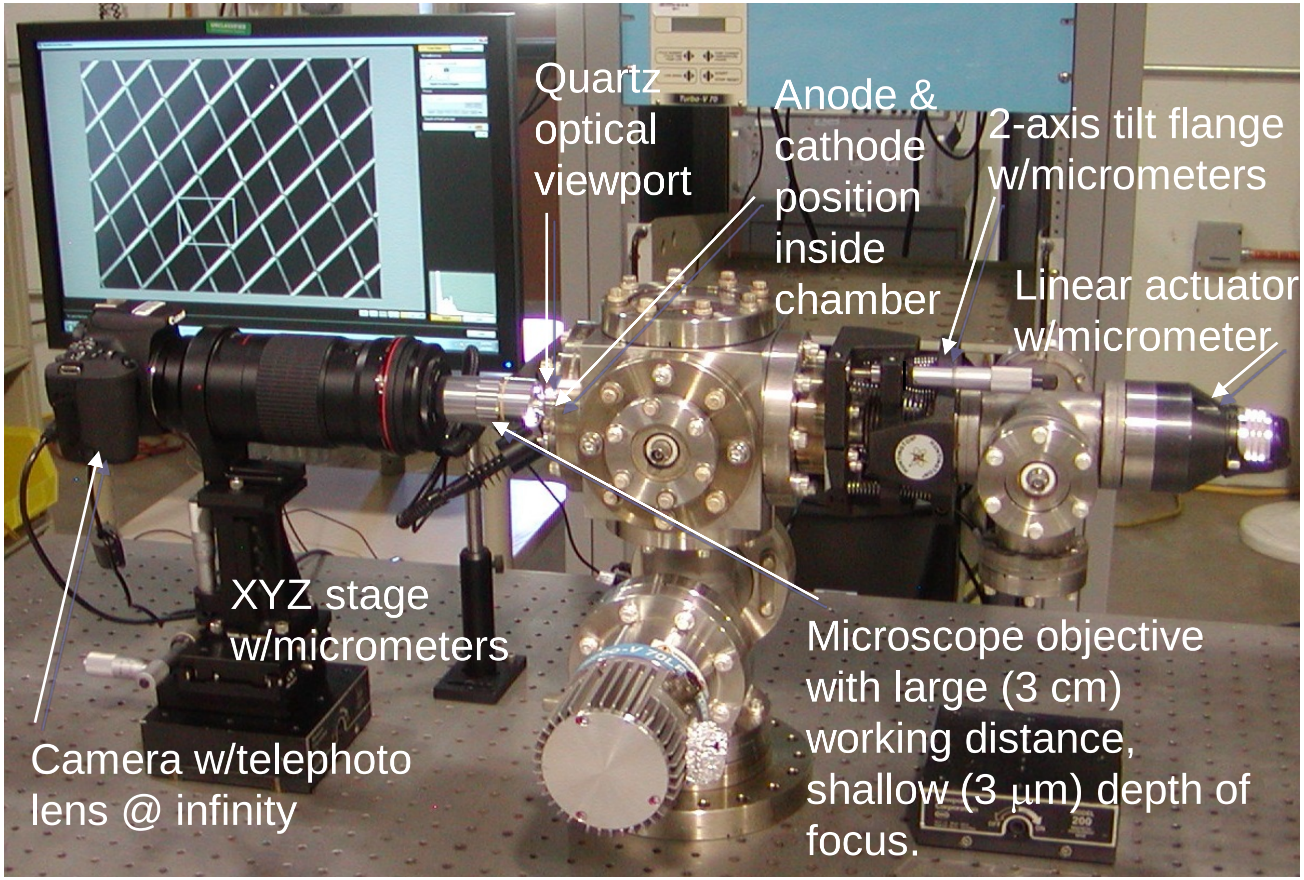
- Dongsung Kim *et al*., "FABRICATION OF MICRON-SCALE DIAMOND FIELD EMITTER ARRAYS FOR DIELECTRIC LASER ACCELERATORS" - Poster (8/14, Tue)
- Dongsung Kim *et al*., “STUDY OF THE BEAM DIVERGENCE IN DIAMOND FIELD EMITTER ARRAY CATHODES" - Poster (8/14, Tue)
- Ryan Fleming *et al*., “A Simple Variable Focus Lens For Field-Emitter Cathodes” - WG6 (8/16, Thurs)
- Chengkun Huang *et al*., “EMISSION MODELS AND BEAM DYNAMICS FOR DIAMOND EMITTERS IN A COMPACT SOURCE OF HIGH BRIGHTNESS BEAMS” – WG5 (8/15, Wed)12

Supplement:
Power Calibration of the Tunable UV Light Source



- Critical step for accurate quantum efficiency calculation
- Most of the “white” background is at 250+ nm, where diamond photocathodes are “blind”

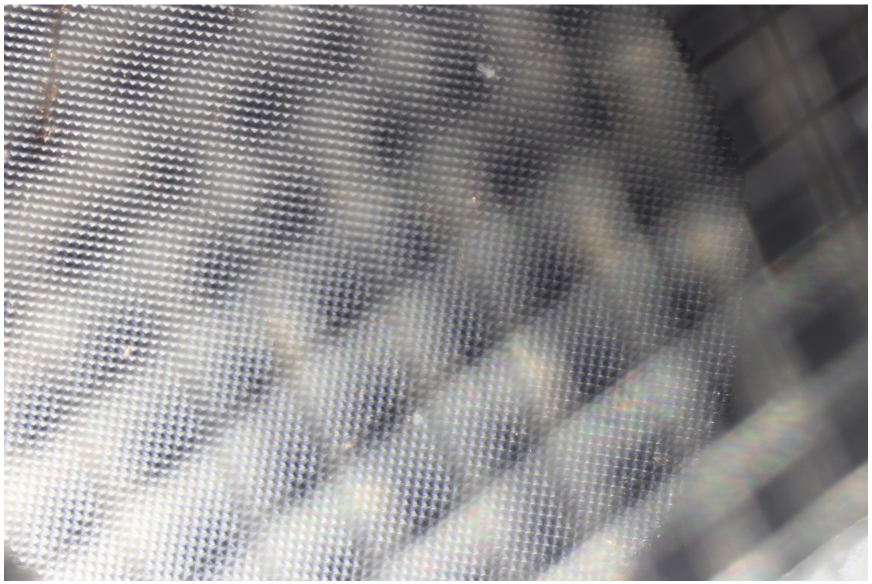
Supplement: Anode-Cathode alignment



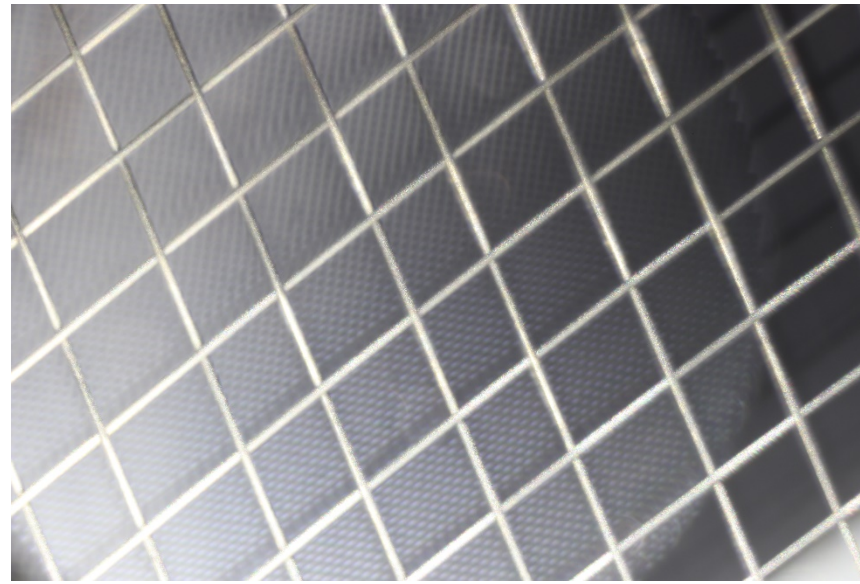
- Cathode is only ~1 cm away from the viewport's outside surface

Supplement:
Alignment of anode mesh vs sample plane

DFEA cathode approx. 250 μm behind anode mesh

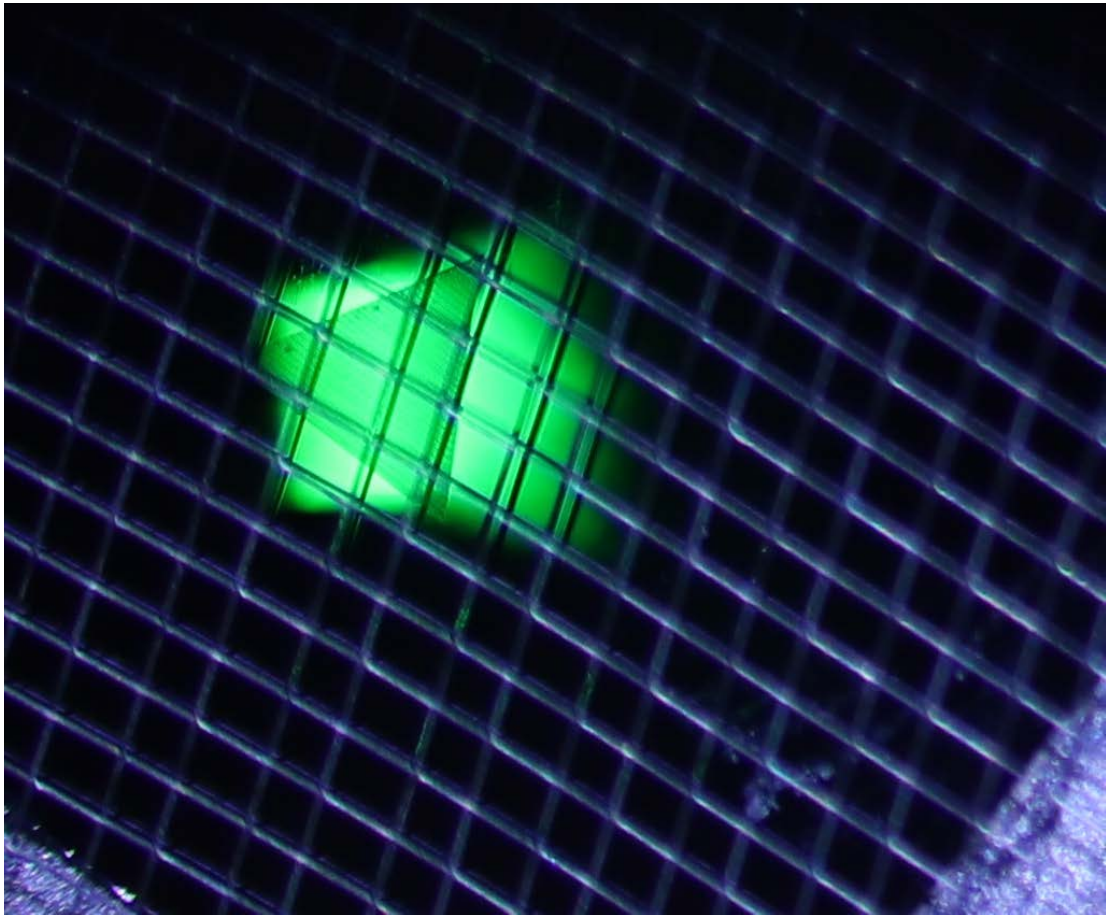


DFEA in focus



Anode mesh in focus

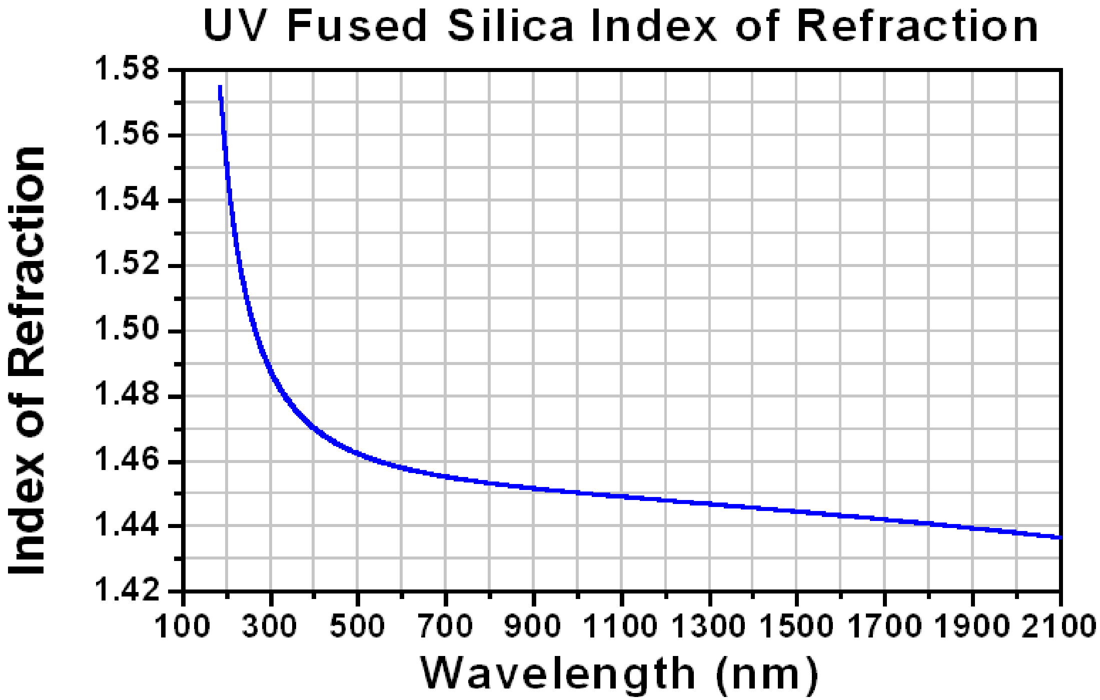
Supplement:
Illumination Spot on DFEA pattern



Output slit of monochromator projected onto DFEA patterned area

Supplement: Correction for 200 nm light

Lensmaker's Equation $$\frac{1}{x_F} = (n-1)\left(\frac{1}{x_{C_2}} - \frac{1}{x_{C_1}}\right)$$



75 mm FL lens will perform approximately as a 60 mm FL lens around 200 nm