Generation of Patterned Electron Beams with Microlens Arrays

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Outline

- Motivation
- Microlens Array setup
- Optical transport design
- Initial laser tests at FAST facility
- Electron beam experiments at AWA facility
- First results and future planned experiments

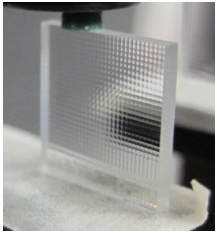
* FAST - Fermilab Accelerator Science and Technology facility

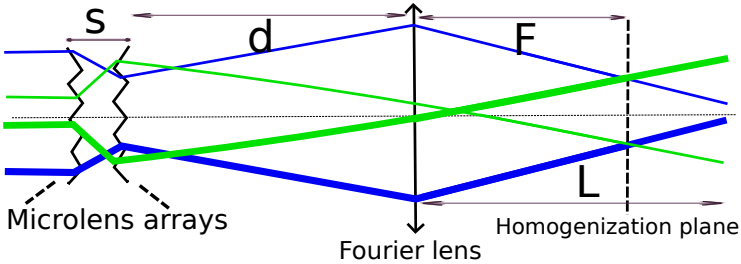
** AWA - Argonne Wakefield Accelerator

Microlens arrays (MLAs)

Motivation: In photocathodes the achievable electron beam parameters are controlled by the laser used to trigger the photoemission. Non-ideal laser distribution hampers the final beam quality, and to overcome this, laser shaping methods are routinely employed.

Microlens arrays are fly-eye type light condensers





1. Produce uniform laser image in the focal plane of the mixing lens
2. Produce transversely modulated laser beams

Some useful expressions

We employed ABCD-model for the MLA setup. We find the diameter of the image at the homogenization plane to be:

$$D_h \approx \frac{Fp}{f^2}(2f - s)$$

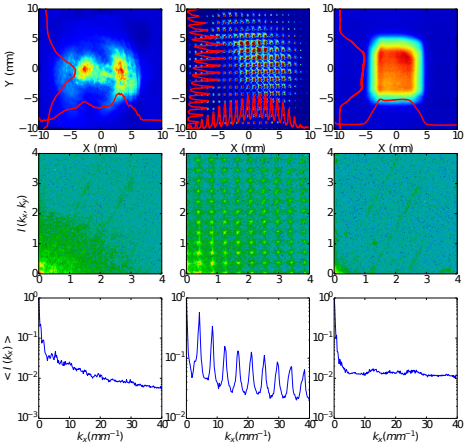
It is also useful to estimate the required lens aperture:

$$A_F \approx \frac{dp}{f^2}(2f - s)$$

Practical implication may sometime result in $L \neq F$; then the size of the image is:

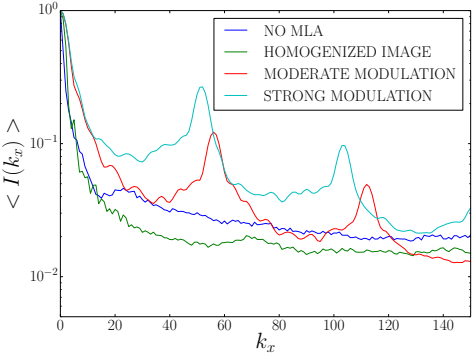
$$D \approx \frac{pL}{f^2}(2f - s) + \frac{dp(2f - s)}{f^2}\frac{F - L}{F}$$

Laser image analysis



(left) Initial laser profile, (middle) patterned beam, (right) uniform beam

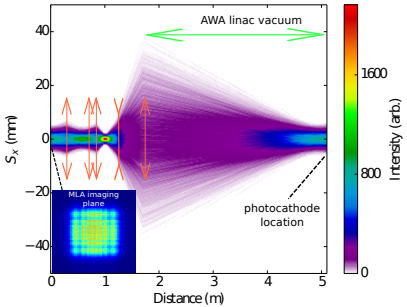
Transverse modulation for different MLA settings (low frequency modulation is dramatically improved!)



Optical transport design

1. Photocathodes often have long optical injection (limited by vacuum)
2. Require imaging solution (not 4F imaging)
3. Lens setup below can be further optimized (this is just a first trial)

Ray tracing of a five-lens transport capable of imaging the homogenized beam at the photocathode. The inset shows of a 8 × 8 array simulated using SRW.



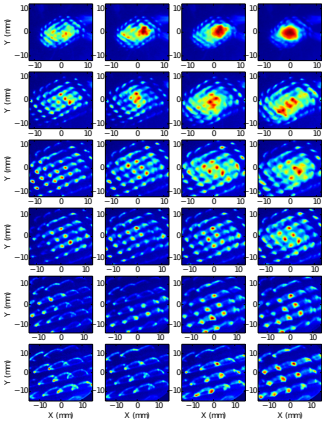
The schematics of the AWA linac (50 MeV) beamline

- Beam images were taken at low (8 MeV) and high (50 MeV) energy
- Various solenoid settings were tested to study the transport of patterned beams

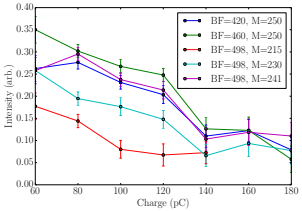
*AWA - Argonne Wakefield Accelerator

Electron beam experiment

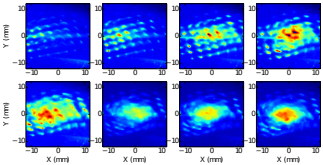
False color 8 MeV electron beam patterns for various matching solenoid current setting and charge. Left to right: Q=60pC, 80pC, 100pC, 120pC. Top to bottom: M=215A, 230A, 241A, 255A, 270A, 290A and BF=498A



Bunching factor as a function of different solenoid settings for low energy beam



False color 50 MeV electron beam patterns for various charges. From left to right and top to bottom: Q=60pC, 100pC, 200pC, 300pC, 400pC, 500pC, 600pC, 700pC



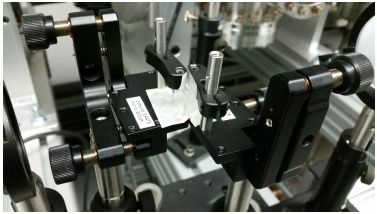
Conclusions

Applications of homogenized beams

1. Significantly improve the quality of the electron beam
2. Reduce transverse beam emittance by factor of 2 (verified with simulations and quadrupole scan measurements)

Applications of patterned beams

1. Provide an excellent beam based method for matching real machine parameters with simulation settings (work in progress)
2. Can be used in multiple THz radiation generation schemes (work in progress)
3. May be used as an alternative to slits in electron beam magnetization measurement (work in progress)



The results were recently reported at IPAC2016 (THPOW021, Halavanau, A., et. al.).

Existing and possible future collaborations

MLA is planned for installation at
Fermilab Accelerator Science and Technology facility (FAST)

1. Argonne Wakefield Accelerator (AWA) facility
   (J. Power, E. Wisniewski, G. Ha, G. Qiang)
2. KEK facility (A. S. Aryshev)
3. ALS Accelerator Physics Group, LBNL (F. Sannibale)
4. SLAC (D. Ratner)

Thank you!