Optical Synchrotron Radiation Beam Imaging with a Digital Mask*

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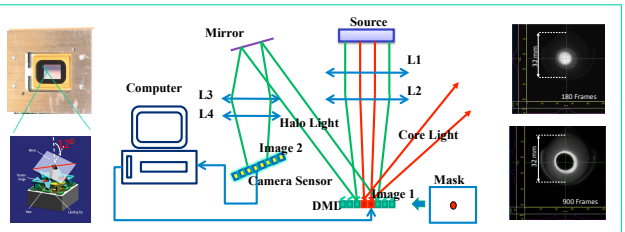
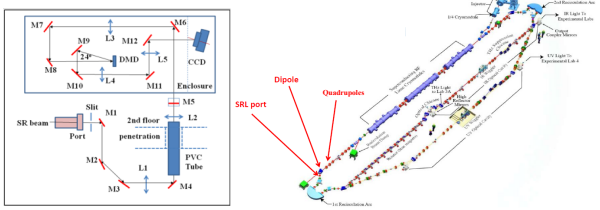
Abstract: We have applied a new imaging/optical masking technique, which employs a digital micro-mirror device (DMD) and optical synchrotron radiation (OSR), to perform high dynamic range (DR) beam imaging at the JLAB Energy Recovery Linac and the SLAC/SPEAR3 Synchrotron Light Source. The OSR from the beam is first focused onto the DMD to produce a primary image; selected areas of this image are spatially filtered by controlling the state of individual micro-mirrors; and finally, the filtered image is refocused onto a CCD camera. At JLAB this technique has been used successfully to view the beam halo with a DR ~ 10^5. At SPEAR3 the DMD was used to filter out the bright core of the stored beam to study the turn-by-turn dynamics of the 10^{-3} weaker injected beam. We describe the optical performance, present limitations and our plans to improve the DR of both experimental systems.



DMD dimensions: 14 x 10 mm
Switching rate: 9600 fps
Individual pixel addressable

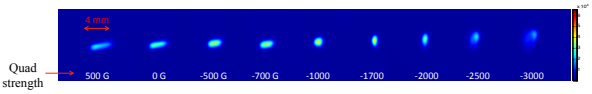
Pixels: 1024 x 768,
Pixel dimension: 14x14 µicrons

Experiment setup at JLAB FEL Facility



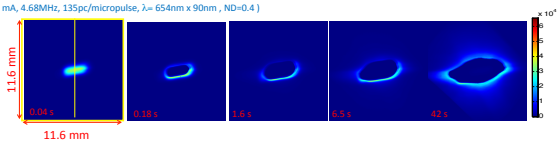
Quadrupole Scan Using OSR with Tune-up Beam

(E=135 MeV, I= 0.32mA: 2Hz rep-rate, 250µs macro, 4.68MHz micro, 135pC/micro)

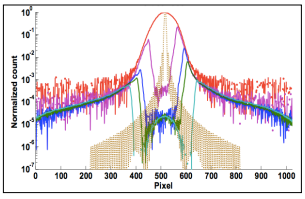


OSR Halo Imaging of JLAB CW beam with DMD threshold mask

(I = 0.63 mA, 4.68MHz, 135pc/micropulse, λ= 654nm x 90nm , ND=0.4)

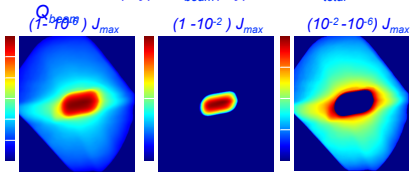


NORMALIZED VERTICAL LINE SCANS



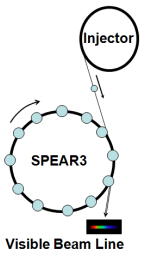
Reconstructed intensity distribution and calculated total radiant energy

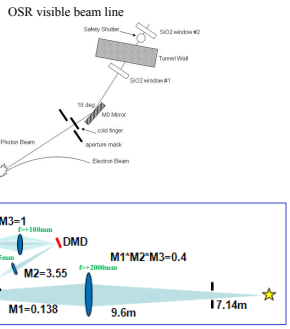
Assume $J(x,y) \sim J_{beam}(x,y)$ => $E_{total} \sim Q_{beam}$



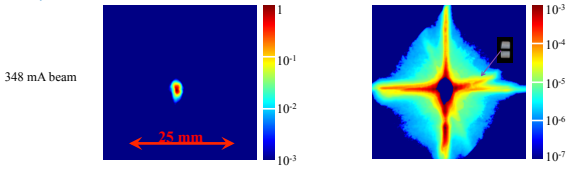
$E_{Total} \equiv \int_S J(x,y)dxdy$ $E \sim 0.99\,E_{Total}$ $E \sim 0.01\,E_{Total}$

Experiment setup in SSRL

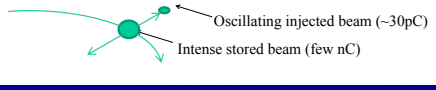


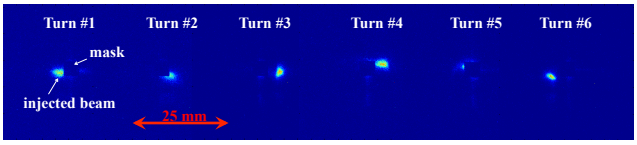


Point spread function

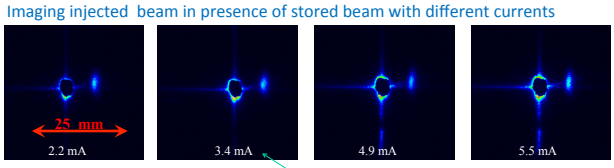


Imaging injected beam turn by turn in presence of stored beam





Imaging injected beam in presence of stored beam with different currents



15 buckets => 15 gates per exposure
Total current = current in each bucket x 15

Current per bucket

Future Plans

JLAB

1. Background measurements and verify halo is not due to stray light from upstream internal sources
2. decrease optical magnification onto DMD and /or increase current density via current, focusing/tune
3. Measure PSF of optical system using highly focused (100 micron) beam
4. Add Lyot and/or apodizing stops to decrease effect of diffraction

SLAC/SPEAR3

1. Install dark transport tubes and baffles to minimize stray light
2. Measure PSF with image-quality ND filters and narrow-band color filter
3. Image injected beam in 350 mA operations (data every 5 minutes)
4. Utilize image data to optimize beta-function match of injected beam
5. Optimize injection efficiency in microbunch mode (low-alpha optics)
6. Model and compare impact of non-linear optics on injected beam

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