Present and Past Research Activities in Beam Diagnostics at The University of Maryland

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Past Activities – Standard Beam Diagnostics:

- Interceptive imagers for beam profiling and emittance measurement
- Fast current monitors (Rogowski, Bergoz, Faraday cup, wall current)
- Energy analyzer

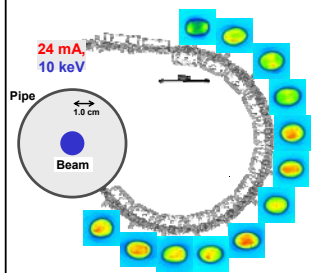
Abstract

The University of Maryland Electron Ring (UMER) is designed for the transport of low energy (10 keV), high current (100 mA) electrons in a 72-magnetic-quadrupole lattice over an 11.52 m circumference. With these parameters, and a typical single-particle phase advance per period of $\sigma_0 = 76^0$, space charge is extreme. Diagnostics are critical to achieving the goal of 100 turns at high current with minimum beam losses and emittance growth by a factor of less than 4. To this end, the UMER beam is diagnosed with both interceptive and non-interceptive diagnostics: slow and fast (few ns rise-time) fluorescent screens, pepper-pot, slit-wire emittance meter, capacitive beam position monitors, fast Bergoz and wall current monitors, and a high resolution energy analyzer. In addition, advanced time-resolved, high resolution diagnostics based on optical transition radiation and intensified gated cameras have been developed for the low energy beam in UMER.

Advanced Beam Diagnostics:

- Time-integrated tomography (via quadrupole or solenoid scan)
- Optical transition radiation (OTR)
- Bunch "slicing" with fast phosphor + gated ICCD camera
- Time-resolved tomography

Fluorescent Screen P43

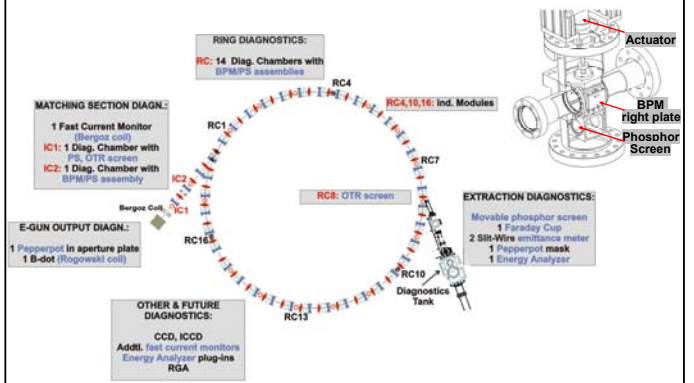


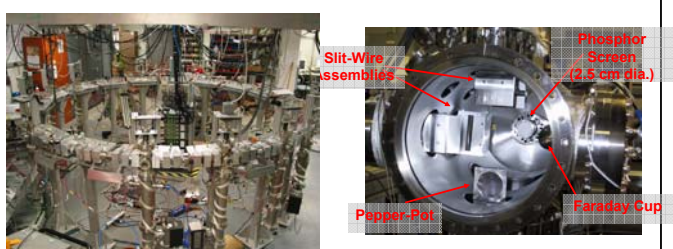
UMER Parameters

Circumference	11,52 m
Full lattice period	0,32 m
No. of quads / peak gradient[1]	72 / 7,8 G/cm
No. of dipoles / field[2]	36 / 15 G
Energy, $\beta = v/c$	≤ 10 keV, 0,2
Initial Emittance (norm., rms)	< 3 μm
Average beam radius	< 10 mm
Vacuum pipe radius	25,4 mm
Tune depression	> 0,16
Pulse length	30-100 ns
Lap time	197 ns

[1]For 76^0, zero-current phase advance per period
[2]For 10^0 bend assuming earth's field compensation

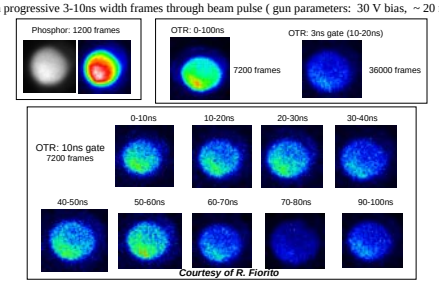
University of Maryland Electron Ring (UMER)





Comparison of full frame beam images taken with gated ICCD camera

with progressive 3-10ns width frames through beam pulse (gun parameters: 30 V bias, ~ 20 mA)



Courtesy of R. Fiorito

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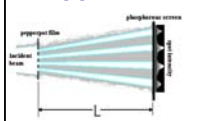
Phase-Space Beam Tomography

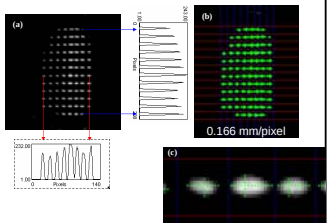
- Variation of magnet strength rotates the phase space distribution
- Beam profiles on the screen (configuration space) correspond to projections of phase space
- Issues:
  - Minimum No. of projections & total angle
  - Modeling of space charge & role of nonlinearities

*D. Stratakis et al, Phys. Rev. ST AB, 9, 112801 (2006)

Pepper-Pot Emittance Meter- Example



10keV, 100 mA, 70^0 experiment



Calculating emittance and plotting phase space

$\langle x \rangle = (1/I_{tot}) \Sigma_{m,n} [x_{m,n} I_{m,n}]$, $\langle x' \rangle = (1/I_{tot}) \Sigma_{m,n} [x'_{m,n} I_{m,n}]$,

$\langle x^2 \rangle = (1/I_{tot}) \Sigma_{m,n} [(x_{m,n} - \langle x \rangle)^2 I_{m,n}]$,
$\langle x'^2 \rangle = (1/I_{tot}) \Sigma_{m,n} [(x'_{m,n} - \langle x' \rangle)^2 I_{m,n}]$,

$\langle xx' \rangle = (1/I_{tot}) \Sigma_{m,n} [(x_{m,n} - \langle x \rangle)(x'_{m,n} - \langle x' \rangle) I_{m,n}]$

The meaning of emittance used for this system is the 4*RMS emittance, defined implicitly (along with normalized emittance) by:

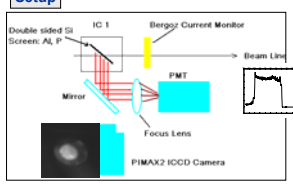
$\varepsilon^2_{rms} = \langle x^2 \rangle \langle x'^2 \rangle - \langle xx' \rangle^2$ $\varepsilon_{norm} = \beta\gamma\varepsilon_{rms}$.

Phase-space plots are made (on four separate axes) of the following four sets:
$((x_m, y_n))_{ij}$ $((x_m, x'_n))_{ij}$ $((y_m, y'_n))_{ij}$ $((x'_m, y'_n))_{ij}$

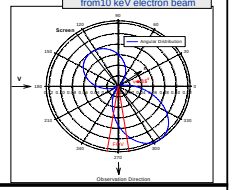
ε_X = 67 μm, ε_Y = 55 μm

Optical Transition Radiation (OTR)

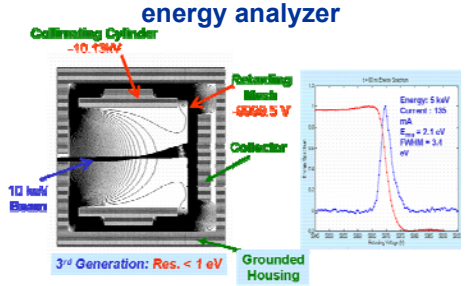
Setup



Angular Distribution of OTR from10 keV electron beam

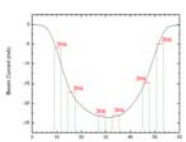


High resolution retarding-field energy analyzer

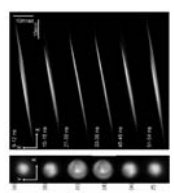


Y. Zou and Y. Cui

Time-Resolved (Solenoid Scan) Tomography



Parabolic current pulse



Sliced phase and configuration spaces

D. Stratakis et al, Phys. Rev. ST AB, 12, 020101 (2009)