NML AARD
Beam Diagnostics Support

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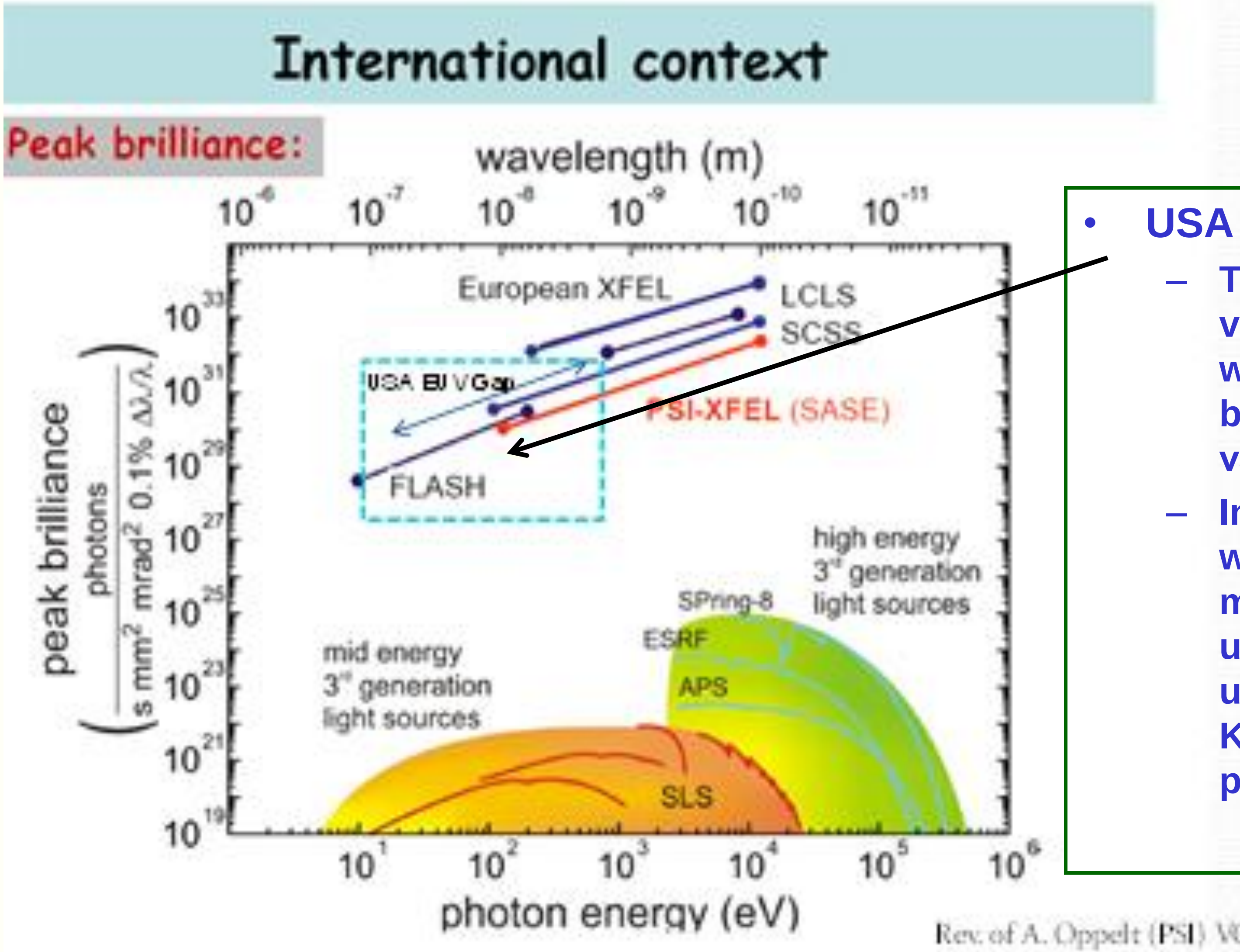
NML Beam Conditions

- NML beam instrumentation and diagnostics systems have to address a large range of beam parameters:
  - From the ILC-TA objective of 3.2-nC micropulses to special low charge (~20 pC) tests with concomitantly lower beam emittance.
  - Various bunch configurations within the macropulse require single bunch measurement capability of some diagnostics devices.
- NML beam commissioning and basic beam measurements with “standard” diagnostics
  - Beam / bunch intensity (Bergoz toroid or WCM)
  - Beam / bunch orbit and energy (BPMs with button detectors and analog/digital read-out sytem)
  - Beam profile / emittance using OTR/YAG/LSO screen monitors
- Support of AARD experiments
  - Supply special beam diagnostics needs.

Diagnostics Developments

- Examples of beam instrumentation R&D
  - Synchrotron radiation (SR) from dipole sources at 40 MeV and 500 MeV for beam size and bunch length (FB applications).
  - Optical diffraction radiation (ODR) for non-intercepting relative beam size, position, and bunch length. (E >500 MeV)
  - Optical transition radiation (OTR) for small beam sizes and investigation of linear polarization effects and OTR point spread function effects.
  - Demonstration of mitigation concepts for COTR from the microbunching instability following bunch compression.
  - Electro-optic sampling (EOS) for non-intercepting bunch length and high resolution phase stability aspects.
  - Other laser-based diagnostics, e.g. laser interferometer.
  - Transverse RF deflector for slice emittance studies (at 40 MeV).
  - Fiber laser-based timing and synchronization capabilities.
  - High resolution BPM R&D.
  - Bunch-by-bunch FB systems for beam stabilization.

Potential EUV SASE FEL at NML



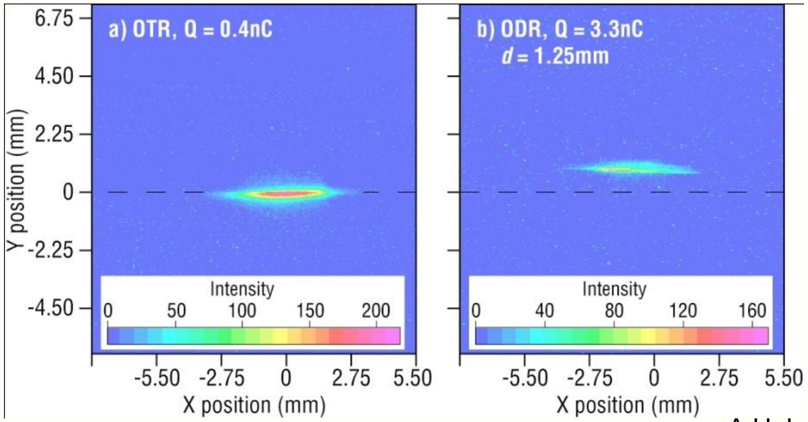
- **USA EUV GAP**
  - These are peak values, but NML will have 15000 bunches per sec vs . LCLS's 120.
  - Initial scaling done with 1 nC, 2 mm mrad, 1 kA peak, up to 1 GeV, with und. 3.3 cm period, K=3.1 in FEL10 paper.

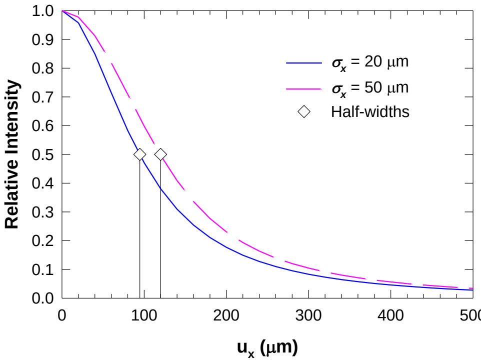
Backup

Investigations of Optical Diffraction Radiation on 1-GeV Beams at ATF are Relevant to ILC-TA Beams

- **ODR offers the potential for nonintercepting, relative beam-size monitoring with near-field imaging. This is an alternate paradigm to previous far-field work at KEK and INFN. This has been proposed for the 1 GeV NML at FNAL.**
- **Propose tests on ATF beams with new scientific CMOS camera by PCO/Andor with very low noise to detect ODR.**
- **Evaluate sensitivities at 10-50 μm sigma. Test ODR PSF.**

APS test at 7 GeV, 3.3 nC
Done with CCD camera,
but larger beam size case.





A.H. Lumpkin et al., Phys. Rev. ST-AB, Feb. 2007

An Analytical Model has been Developed by D. Rule for ODR Near-Field Distributions Based on the Method of Virtual Quanta

- We convolved the electron beam's Gaussian distribution of sizes σ_x and σ_y with the field expected from a single electron at point *P* in the metal plane (J.D. Jackson)

$$\frac{dI}{d\omega}(\boldsymbol{u},\omega) = \frac{1}{\pi^2}\frac{q^2}{c}\left(\frac{c}{\mathrm{v}}\right)^2 \alpha^2 N \frac{1}{\sqrt{2\pi\sigma_x{}^2}}\frac{1}{\sqrt{2\pi\sigma_y{}^2}} \times$$

$$\iint dxdy\ K_1{}^2(\alpha b) e^{-\frac{x^2}{2\sigma_x{}^2}} e^{-\frac{y^2}{2\sigma_y{}^2}},$$

where ω = radiation frequency, v = electron velocity ≈ c = speed of light, q = electron charge, N is the particle number, $K_1(\alpha b)$ is a modified Bessel function with α= 2π/γλ and b is the impact parameter.

A.H. Lumpkin et al., PRST-AB, Feb. 2007

Investigations of OTR at NML

- Interest in the optical transition radiation (OTR) point spread function (PSF) and investigation of anomalous polarization effects reported in JLAB and FNAL A0PI experiments.
- Determine actual beam image size after deconvolving PSF. Perform test with beam size from 100 to 1 μm with various optical angular collection apertures.
- Subsequently apply technique to the ILC-TA beams at NML at 800 MeV.

JLAB test at 4.5 GeV: Pol. OTR image is ~20 μm smaller than total OTR image. This is ~5x more than expected from OTR PSF model.

What happens below 100 μm?