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Proposed Research with Microbunched Beams at LEA

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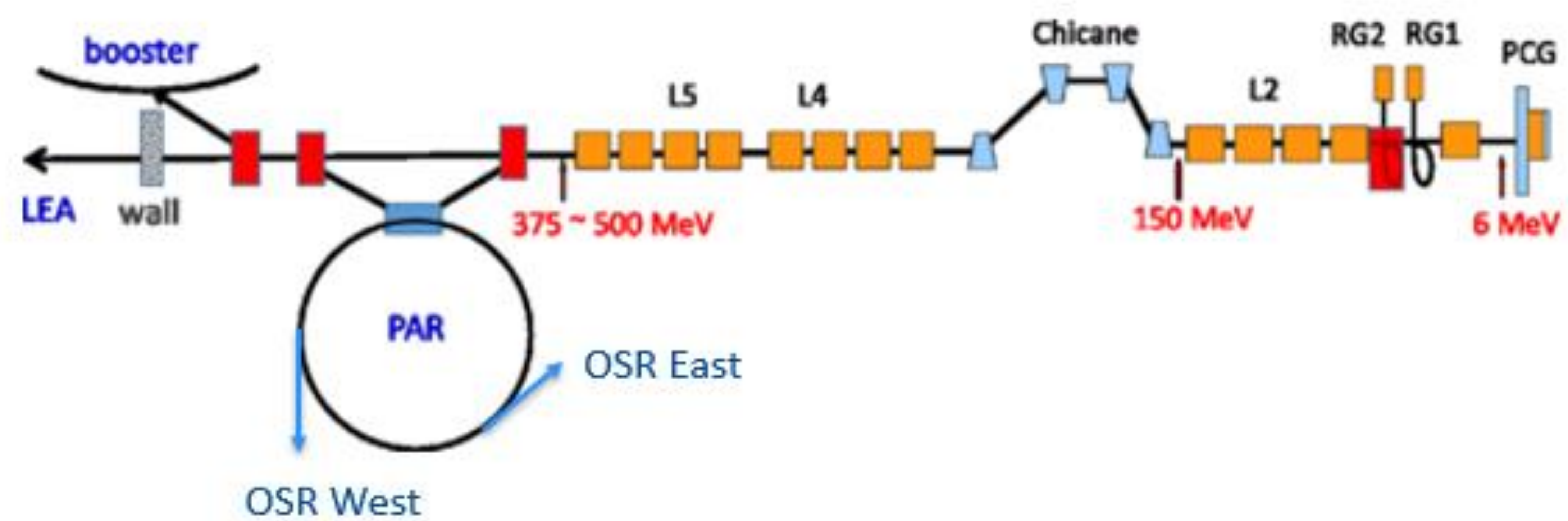
ABSTRACT

Significant microbunching of an electron beam at 266 nm is projected with the co-propagation of electrons at 375 MeV and a UV laser pulse through a 3.2-cm period prebuncher undulator. Such microbunched beams will generate coherent optical transition radiation (COTR) at a metal screen surface boundary or coherent optical diffraction radiation (CODR) from a nearby metal surface. With a 10% microbunching fraction, coherent enhancements of more than 7 million are modelled for a 300-pC charge. Diagnostic plans are described for beam size (100 μm), divergence (sub-mrad), electron micro-bunching fraction, spectrum, and bunch length (sub-ps) on a single shot at the Argonne National Laboratory Linac Extension Area (LEA) facility.



Schematic of the APS linac showing the path to the PAR or to the LEA tunnel.

Table 1: Linac Parameters for PC Gun Beam Used in the Proposed Tests

Parameter	Units	Value
Energy	MeV	375
Charge	pC	100-300
Emittance	mm mrad	2-4
Bunch length	ps	0.5-2.0

The number of OTR photons emitted by a single electron per unit frequency ω per unit solid angle Ω,

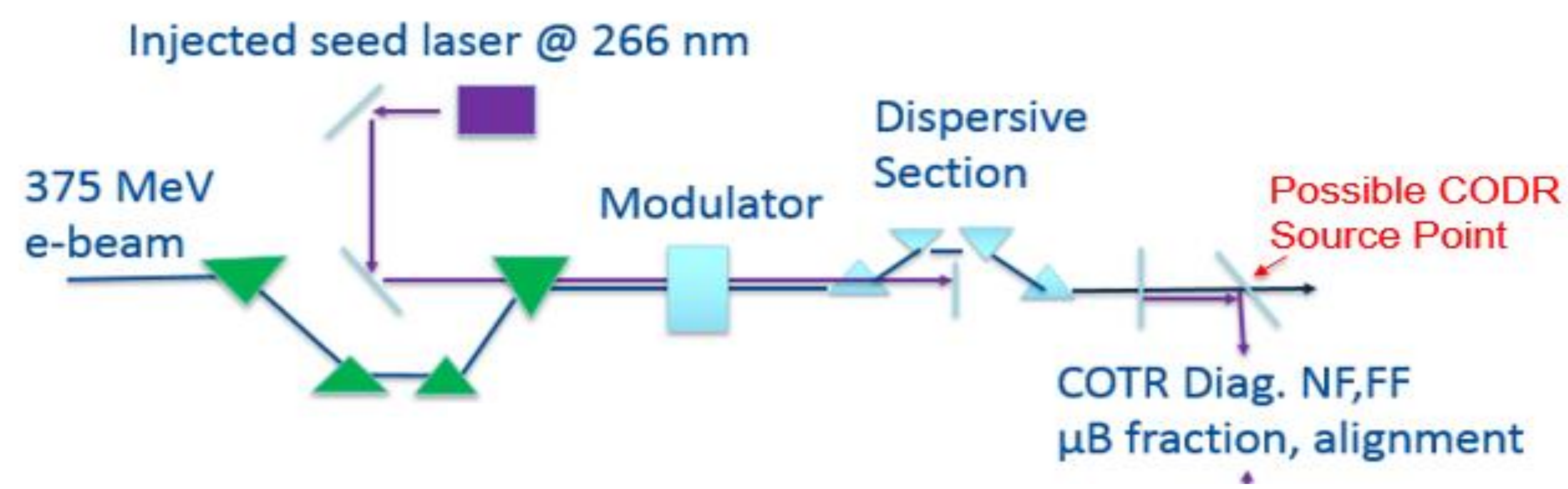
$$\frac{d^2W_1}{d\omega d\Omega} = \frac{e^2}{\hbar c}\frac{1}{\pi^2\omega}\frac{(\theta_x^2+\theta_y^2)}{(\gamma^{-2}+\theta_x^2+\theta_y^2)^2} .$$

$$\frac{d^2W}{d\omega d\Omega} = |r_{\parallel,\perp}|^2\frac{d^2W_1}{d\omega d\Omega}[N\boldsymbol{I}(\boldsymbol{k}) + N_B(N_B-1)\boldsymbol{J}(\boldsymbol{k})],$$

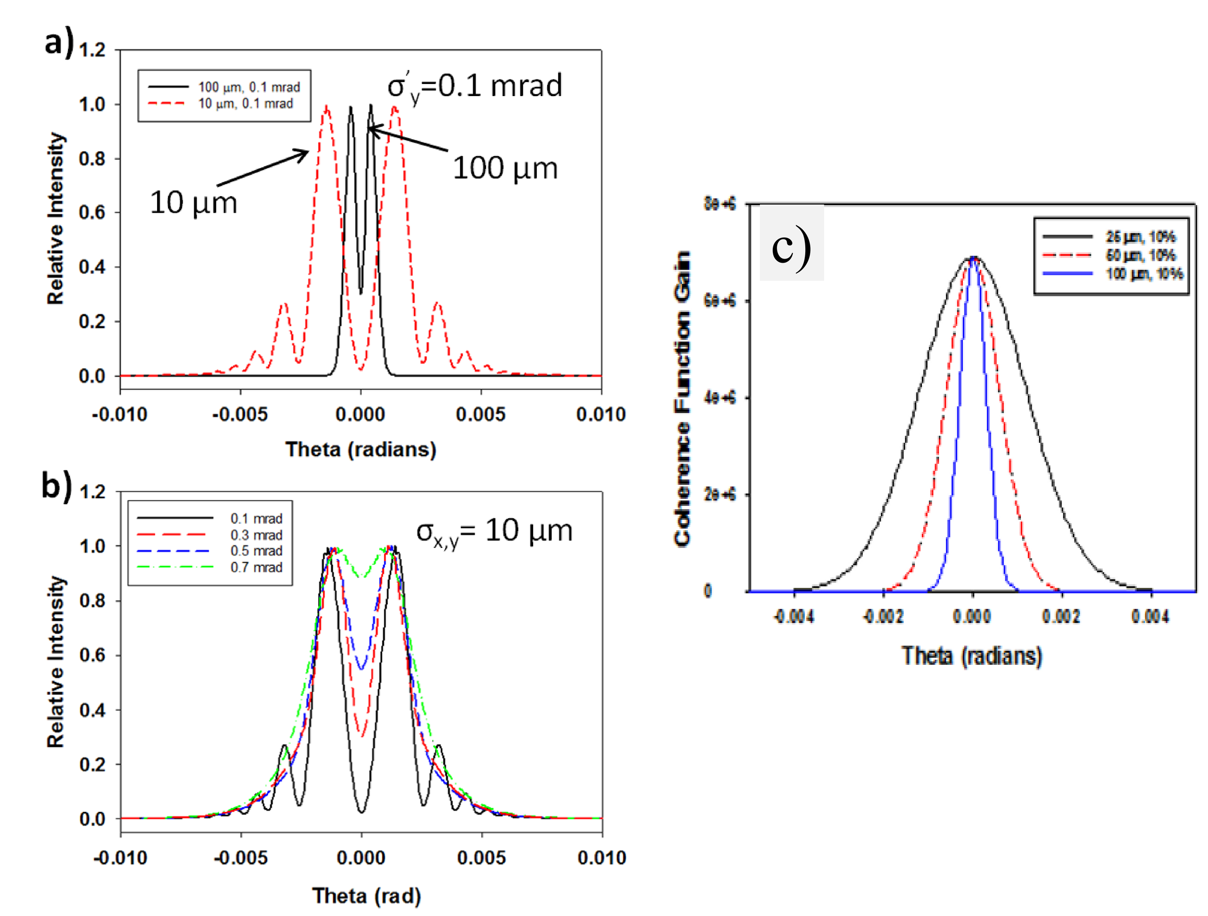
$$\boldsymbol{I}(\boldsymbol{k}) = 4\sin^2[\frac{kL}{4}(\gamma^{-2}+\theta_x^2+\theta_y^2)] ,$$

where N_B of the total number N are microbunched, i.e., the bunching fraction, bf= N_B/N. Here $|r_{\parallel,\perp}|^2$ is the reflection coefficient for parallel or perpendicularly polarized OTR

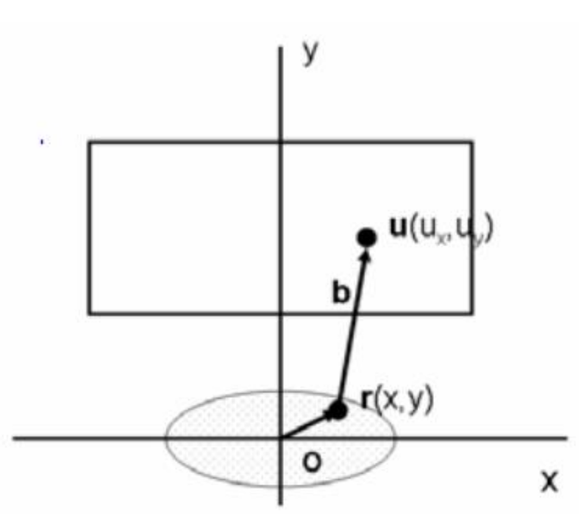
Schematic of the proposed seed laser, modulator, dispersive section, and diagnostics chamber in the LEA tunnel.



COTRI model results a) beam size effects at 10 and 100 μm (b) divergence effects c) Coherence function gain at 7 million for small angles.



The geometry for the simulation, u is the observation point of ODR. r is the location of an electron of the beam. The shaded area represents the passing beam.



Incoherent near field ODR equation where *b* is the impact parameter, $\alpha = 2\pi/\gamma\lambda$, and *N* is the number of particles. K_1 is the modified Bessel function.

$$\sum_{i=1}^{N_B}|E_y^i|^2 \to \langle|E_y(u,\omega)|^2\rangle = N\frac{e^2\alpha^2}{\pi^2v^2}\iint dxdy\frac{b_y^2}{b^2}K_1^2(\alpha b)F_\perp(x,y) \quad (7)$$

The NF CODR equations then become the following, where N_B is the number of microbunched electrons. The N_B squared term gives the large coherent enhancement of CODR.

$$N_B(N_B-1)\langle E_y^1(u,\omega)\rangle\langle E_y^2(u,\omega)\rangle^* = N_B(N_B-1)\frac{e^2\alpha^2}{\pi^2v^2}e^{-(\sigma_z k_z)^2}\left|\iint dxdy\frac{b_y}{b}K_1(\alpha b)F_\perp(x,y)\right|^2 .$$

SUMMARY

In summary, we have described the potential for measuring a comprehensive set of microbunched electron beam properties on a single shot using COTR and potentially extending the basic techniques to CODR imaging. We presented the new NF ODR model for the first time that will guide future experiments.