Inverse Compton scattering at collision of electron and photon beams with oblique fronts

A.P. Potylitsyn[1] and A.A. Tishchenko[2,3,4]

[1] National Research Tomsk Polytechnic University, Tomsk, Russia
[2] National Research Nuclear University MEPhI, Moscow, Russia
[3] National Research Centre "Kurchatov Institute", Moscow, Russia
[4] Laboratory of Radiation Physics, Belgorod National Research University, Belgorod, Russia

Abstract

Inverse Compton scattering dubbed "light undulator" is a known source of x-ray radiation, bright and intense. Among the perspective directions of research one of the most significant is idea of Debus with co authors: to use the laser pulse with skew front to increase the time of interaction of the electron and photon beams. The corresponding calculations were performed within classical electrodynamics. Here, we calculated this process in terms of luminosity within quantum electrodynamics. Our results show that the condition suggested by Debus et al. for the maximal intensity will not result in the number of the scattered photons compared with the conventional collinear orientation of the fronts.

Motivation

How can we increase the number of photons?

- Increasing *N in e-bunch*.

Yes, but it is limited: space-charge effect.

- use more intense laser

Yes, but: redshift of maximum energy, harmonics generation, ponderomotive broadening, oscillations,…

- decrease the spot-size of an e-beam

Yes, but there will be technical problems

with synchronization; + large emittance – low brilliance.

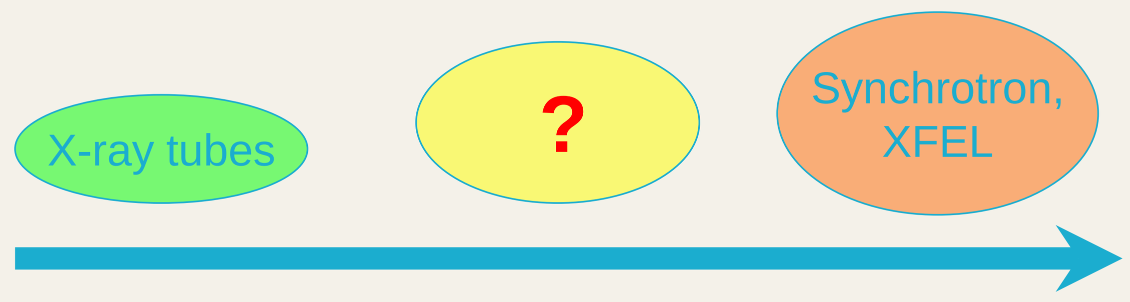
- synchronise the fronts of laser and e-beams - so that the time of interaction would increase! (Debus)

A.D. Debus et al., Appl. Phys. B **100**, 61 (2010).

K. Steiniger, A. Debus et al., Frontiers in Physics **6**, 155 (2019).

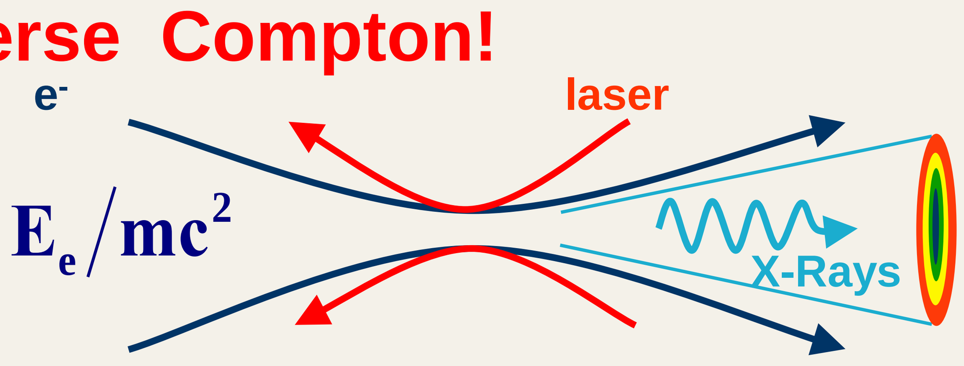
Motivation

	X-ray tube	Synchrotron
Average spectral brightness $s^{-1}mm^{-2}mrad^{-2}0,1\%$	$<10^8$	10^{16}–10^{21}
Divergence, mrad	4π	<0.1
Size, m	0,1–1	20–1000
Price, $10^6$$	10^{-4}–10^{-1}	100–1000



Inverse Compton!

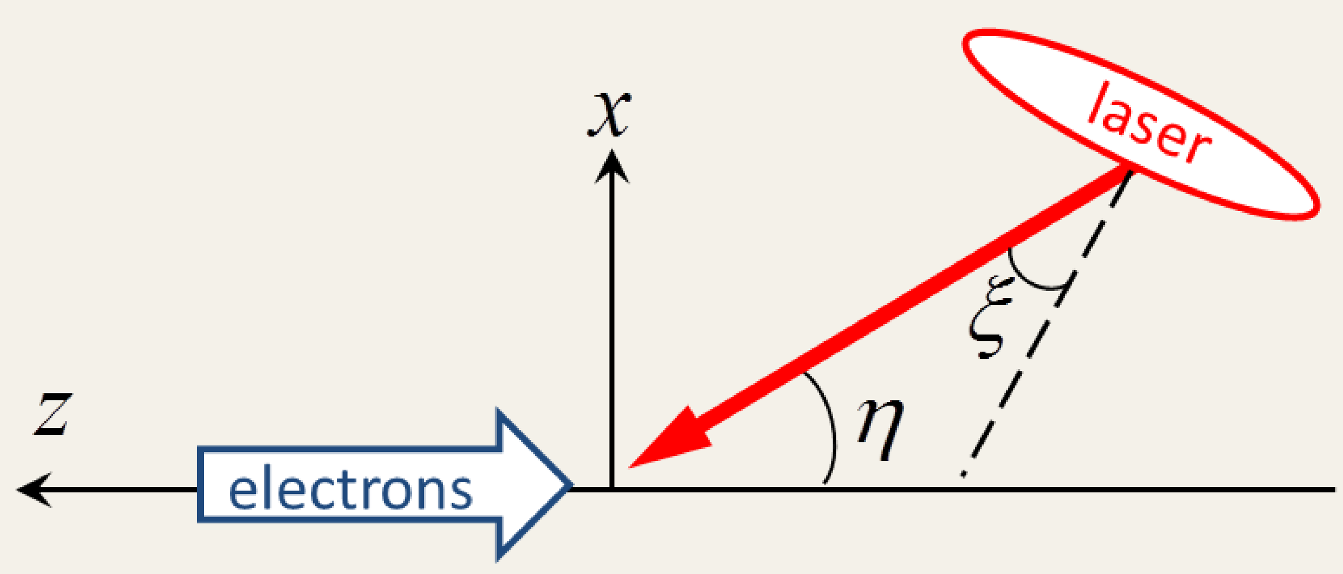
$$E = 4\gamma^2 E_{ph}, \quad \gamma = E_e / mc^2$$



Commercial y available X-ray sources:
Lumitron Technologies; Lyncean: the flux ~10^{11}-10^{13} ph/s

Theoretically predicted average flux ~10^{14} ph/s
W.S. Graves et al., NIM A 608, 103 (2009)

Debus' results - classical electrodynamics.
What will we see in terms of luminosity in quantum electrodynamics?



$$\xi = -\eta/2 \qquad (*)$$

In Debus's papers, Appl. Phys. B 2010, Frontiers in Phys. 2019; see also Bulyak, Phys. Rev. ST AB **8**, 030703 (2005).

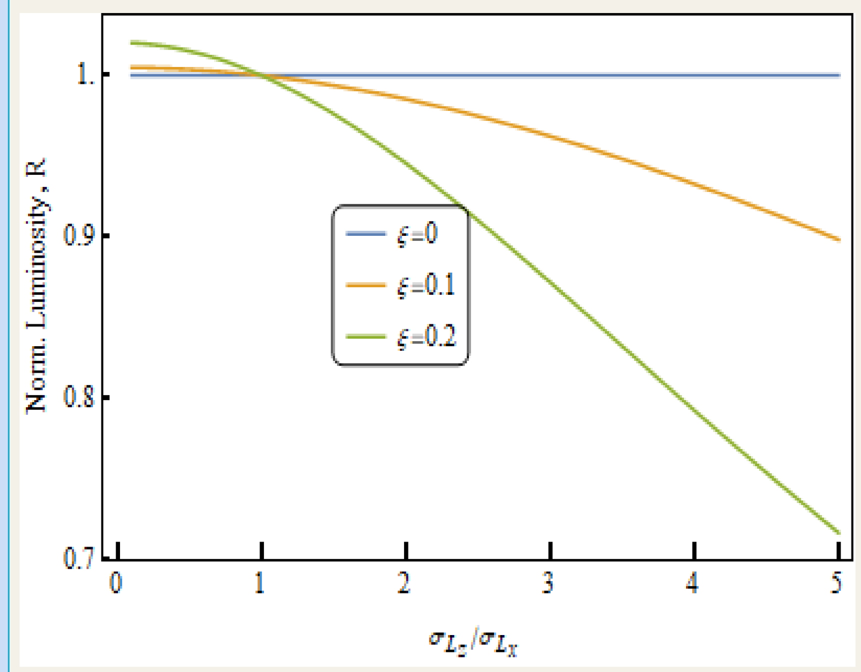
Luminosity, when the size of e-beam is neglected:

$$L = \frac{1}{2\sqrt{2}\,\pi\,\sigma_{L_Y}\cos(\eta/2)} \frac{1+\cos\eta}{\sqrt{\sigma_{L_X}^2 + \sigma_{L_Z}^2 + \left(\sigma_{L_X}^2 - \sigma_{L_Z}^2\right)\cos(\eta + 2\xi)}}$$

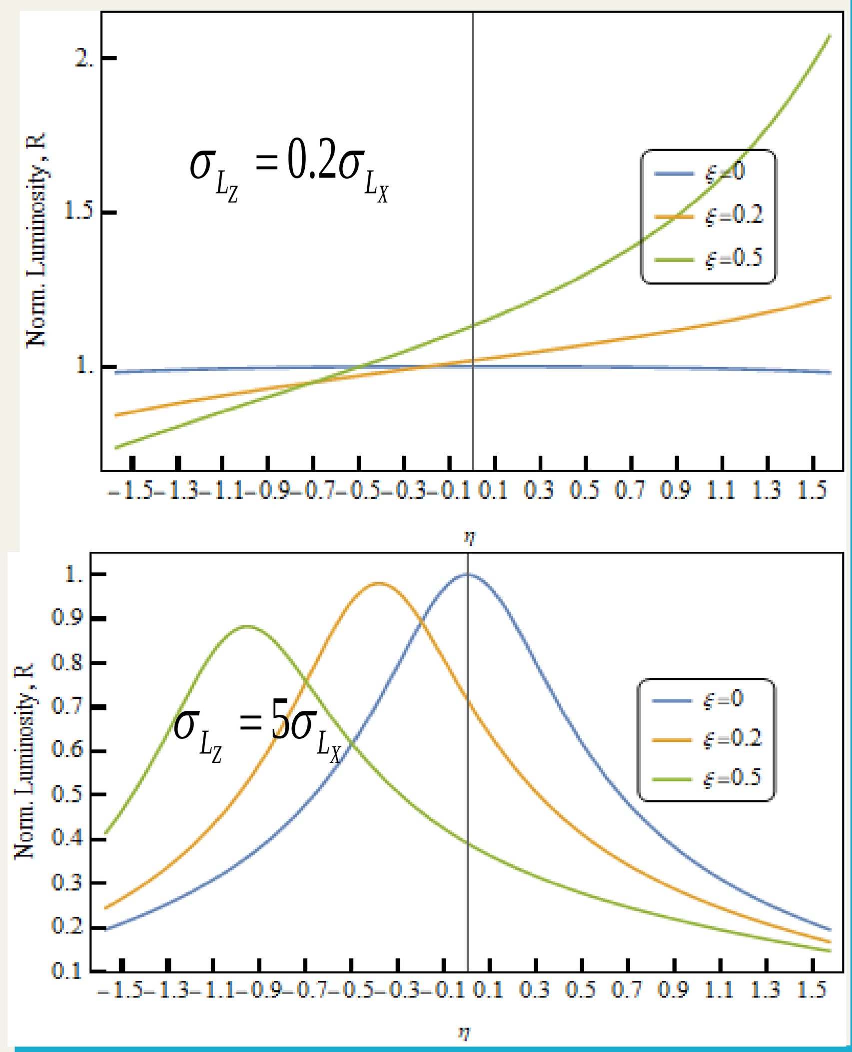
$R(\xi) = L_C(\xi)/L_{0C}$ normalized luminosity – see figures below.

Analysis

Normalized luminosity for a head-on collision depending on the length of the laser bunch at different orientations of the laser front.



Dependence of the normalized luminosity on the angle of noncollinearity η at various angles of inclination of the laser front ξ.



Conclusion

- Condition (*) proposed by Debus et al. to ensure the maximum yield of scattered radiation does not lead to a gain in the number of scattered photons compared to the standard orientation of the laser front in collinear geometry.
- The oblique front of the laser pulse gives a noticeable gain in intensity only for short bunches

$$\sigma_{L_Z} < \sigma_{L_X}$$

and maximum luminosity is achieved for tilt angles

$$\xi \approx \pi/2$$

unlike condition (*).

Acknowledgement

The study was supported by RFBR, grant 19-29-12036.