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Experimental Polarization Control of Thomson Scattering X-ray Source

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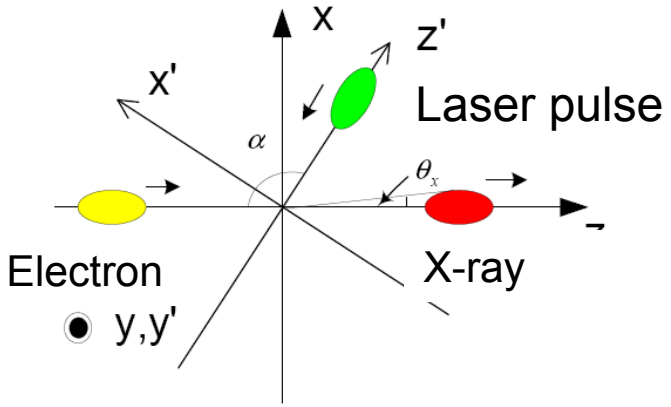
Outline

- Thomson Scattering
- Experiment
  - Setup
  - Design
- Results

Thomson Scattering

- Thomson Scattering
  - Interaction between photon and electron
  - Photon energy≪electron energy（MeV）
- Features
  - Short pulse, high brightness, quasi monochromatic, wavelength continuously tunable(keV~MeV), polarization controllable.
- Application prospects
  - Life Science, biophysics, nuclear physics, X-ray polarization detector calibration and so on.

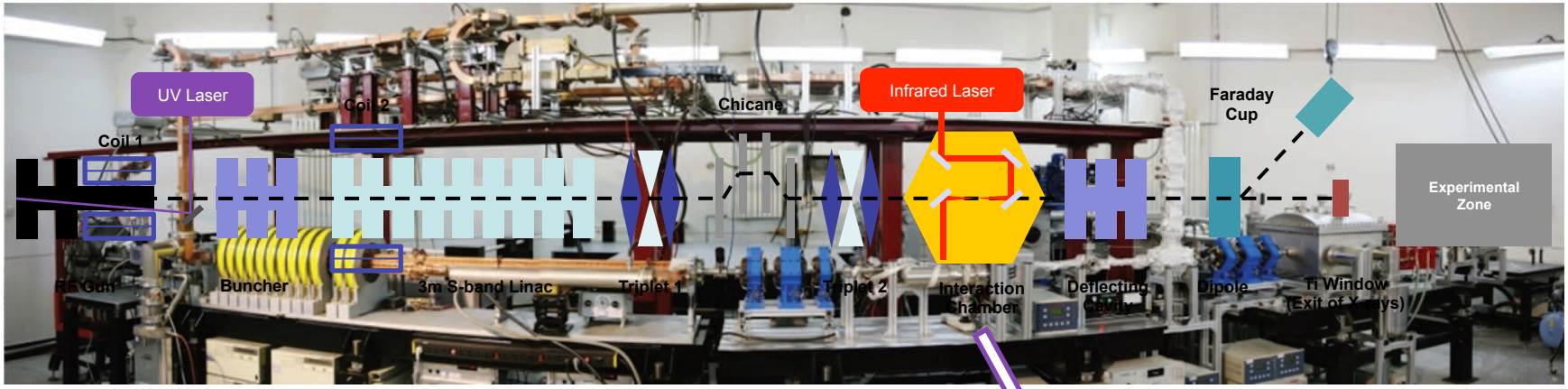


$$\frac{d\sigma}{d\Omega} = r_e^2 \frac{1-\beta^2}{(1-\beta\cos\theta)^2}\left[1-\frac{\sin^2\theta\cos^2 f}{\gamma^2(1-\beta\cos\theta)^2}\right]$$

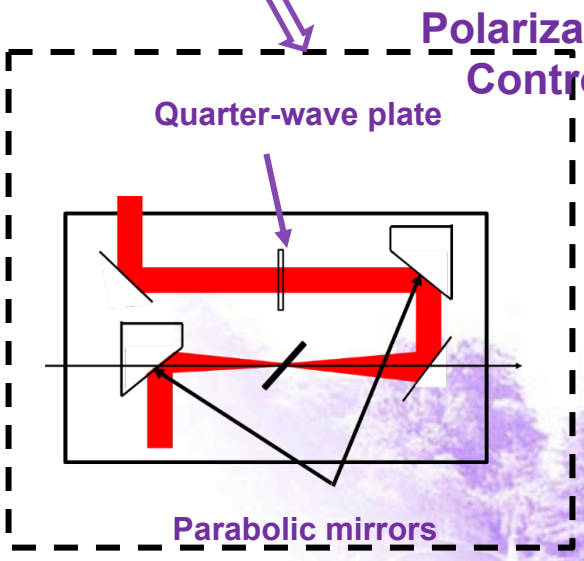
$$\vec{E} = \frac{q}{4\pi\varepsilon c^2 r}\frac{\vec{e}_r \times \left(\vec{e}_r \times \vec{v}\right)}{\left[1-\frac{\vec{v}\cdot\vec{e}_r}{c}\right]^3}$$

J. Yang et al., Nucl. Instr. and Meth. A, 428, pp. 556, 1999.

Tsinghua Thomson Scattering X-ray Source



Parameters	
Photon energy/ keV	~50
Electron energy/ MeV	46.7
Laser wavelength/ nm	800
Count/per pulse	~10^7



Y. Du et al., Nucl. Instr. Meth. A 637, S168 (2011).

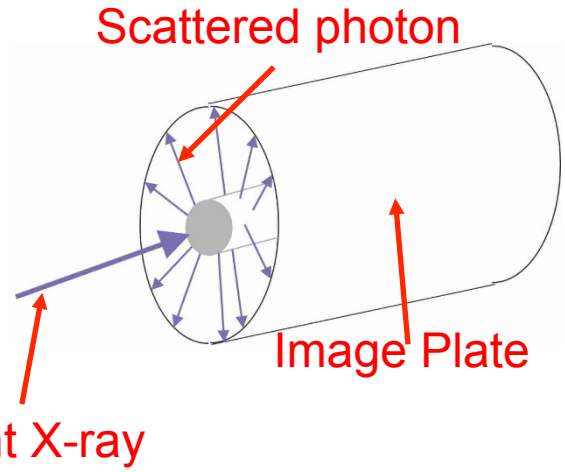
Polarization Measurement

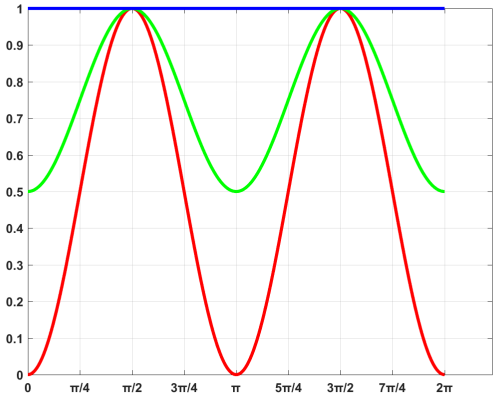
- Polarization measurement methods
  - Photoelectric effect：Soft X-ray
  - Compton scattering effect：Hard X-ray or Gamma ray
- Klein-Nishina formula

$$\frac{d\sigma}{d\Omega} = r_e^2(1-\sin^2\theta\cos^2 f)$$

$$\frac{ds}{dW} = r_e^2\left(1-\sin^2 q\,\frac{\cos^2 f + a\sin^2 f}{a+1}\right)$$

- The cross section distribution is depended on factor a
- a: the ratio of $E\downarrow x$、$E\downarrow y$
- The distribution of scattered photons in space→X-ray polarization

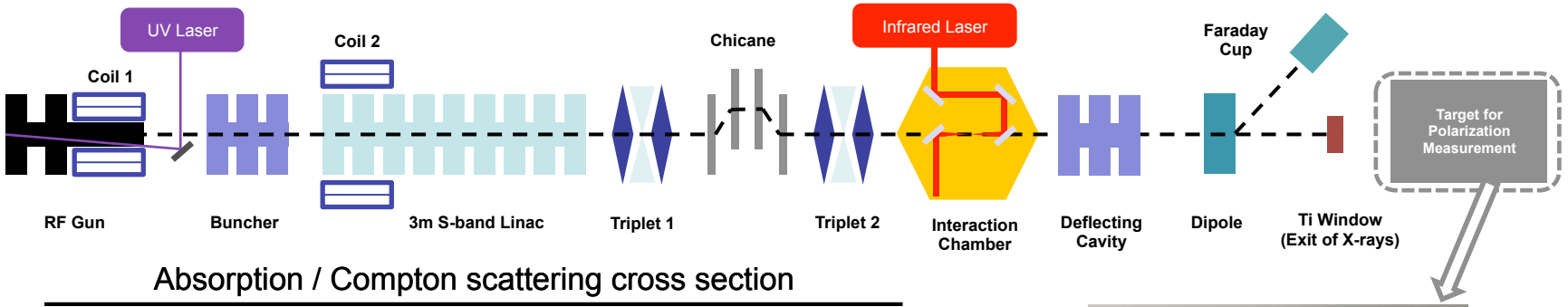




θ=90°

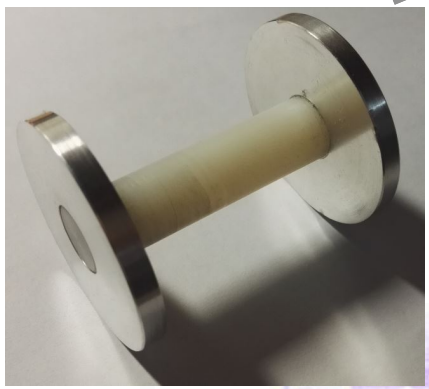
arXiv:1408.5899v1

Experiment Design



Absorption / Compton scattering cross section

Photon energy	Material	Absorption（cm²/g）	Compton scattering（cm²/g）
50keV	PE	0.0089	0.1880
	C	0.0104	0.1630
	Al	0.1720	0.1500
	Fe	1.7000	0.1360
30keV	PE	0.0489	0.1930
	C	0.0571	0.1650
	Al	0.8720	0.1460
	Fe	7.7600	0.1290
10keV	PE	1.7800	0.1670
	C	2.0800	0.1350
	Al	25.6000	0.1060
	Fe	169.0000	0.0854

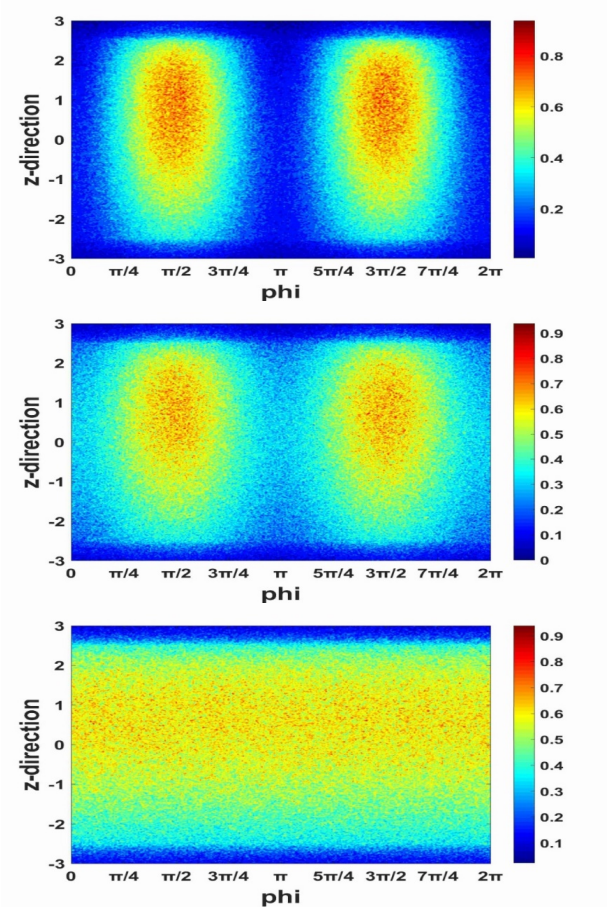


Size：radius1.5-cm, height 6-cm

Aluminum Ring：Inner radius 1.5-cm, outer radius 5-cm, thickness 0.5-cm

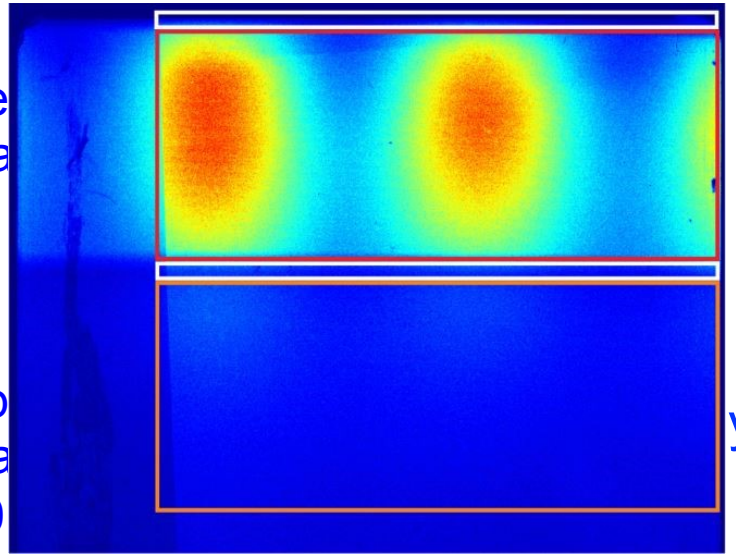
Record scattered photons with image plate

Simulation & Experiment



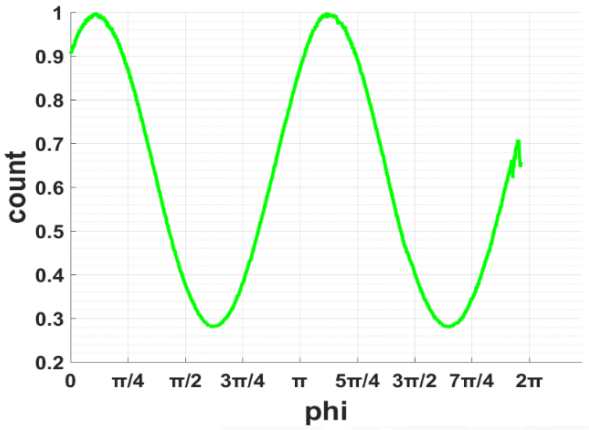
Line
Pola
P=1

Ellip
Pola
P=0

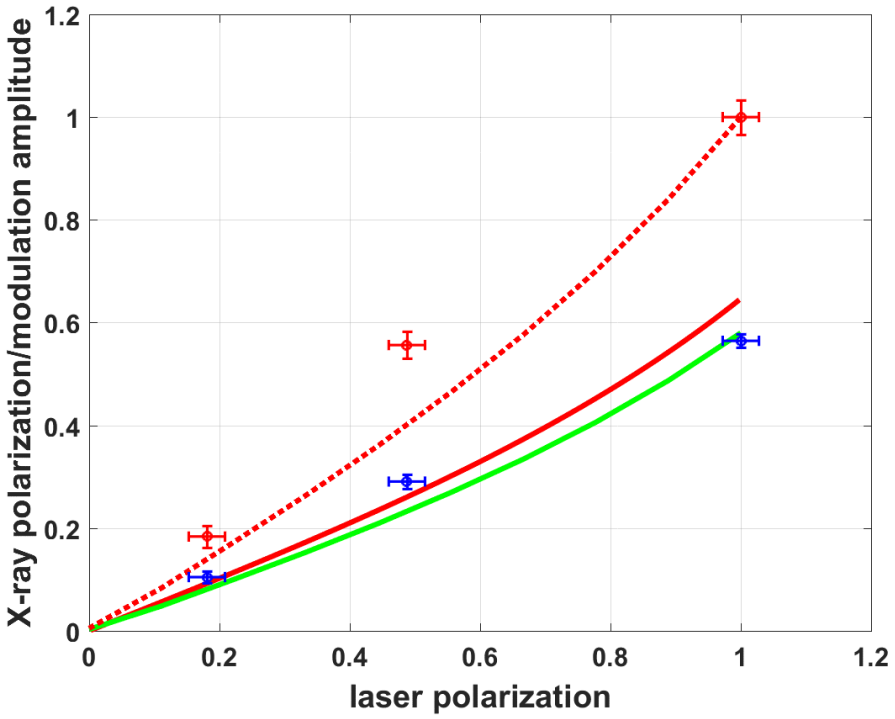


y Geant4

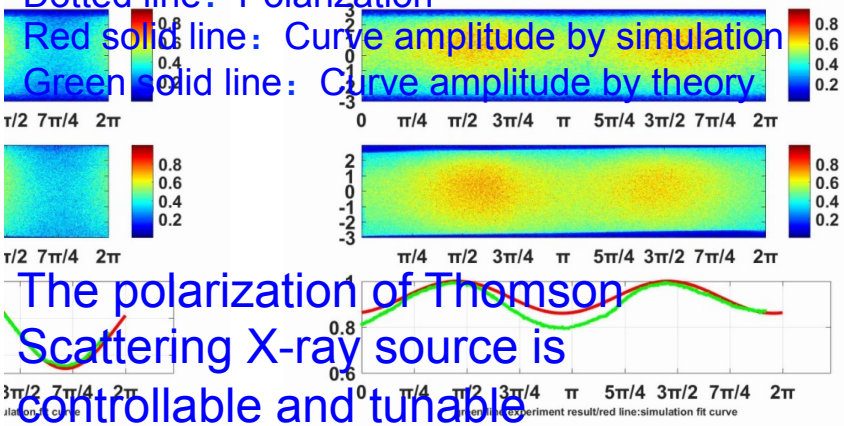
Circle
Polarizat
P=0



Experiment Results



Dotted line：Polarization
Red solid line：Curve amplitude by simulation
Green solid line：Curve amplitude by theory



The polarization of Thomson Scattering X-ray source is controllable and tunable

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$\lambda = 0.1047$

$P = 0.1836$