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Laser beam-electron Compton scattering: technology and applications

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Abstract

The goal of this presentation is to introduce the properties and scientific interests of the laser beam-electron beam Compton scattering. There are many possible applications for this process but the main technical difficulty is the requested very high laser beam average power. The various solutions that are presently worked out to provide the requested average power will be reviewed as well as the various electron accelerator technologies. Finally, the various Compton machine operating at present and the future projects will be described.

General Introduction

Laser electron scattering (see Fig. 1) is a well known process which can provide monochromatic X or gamma ray beams [1]. Such beams can be used in a large application domain. In this presentation we will cover the following topics:

- Properties of the Compton scattering.
- Applications.
- Optical devices needed for Compton X/gamma ray source.
- Accelerator devices needed for Compton X/gamma ray source.
- Status of the Compton project/installation X/gamma ray sources.

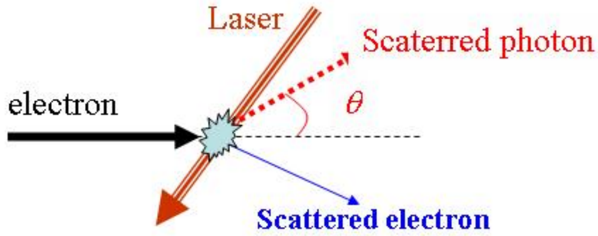

Fig. 1. Schematic view of the laser-electron Compton Scattering.

Properties of Compton scattering

The diffusion of an electromagnetic plane wave by an electron at rest, with mass m_e and charge q, is a process known as 'Thomson scattering' [2]. From a classical point of view, the process can be visualised as a plane wave of frequency ω_0 impinging on a charge. The scattered wave is not plane but, in the approximation where the recoil effect can be neglected (*i.e.* $m_e >> \omega_0$) the electromagnetic wave frequency is conserved. However, the very general formula are derived within quantum electrodynamics [3] where the scattering process is understood as the succession of the absorption and the emission of the photon by the electron and is known as 'Compton scattering'. We shall adopt this latter corpuscular point of view which includes electron recoil effect and polarisation properties [3].

The interest of Compton scattering is related to the kinematical properties of the X/gamma rays. First, the energy distribution exhibits a kinematical limit given by $E_{max} \approx 4\gamma^2\omega_0$ with $\gamma = E_e/m_e$ where E_e is the electron incoming energy. Since $m_e \approx 0.5$MeV one sees that, comparing to synchrotron radiation process [1], the Compton scattering is a very efficient way to boost the laser photon energy. Second, Compton scattering is a two body process so that the angle and energy on the produced X/gamma rays are correlated and $\theta=0$ (see Fig. 1) corresponds to the maximum scattered energy. With a simple collimation system, one can thus produce a quasi monochromatic X/gamma ray beam. Third, depending on the laser beam polarisation, and even for an unpolarised electron beam, one can control the polarisation of the scattered X/gamma rays.

In summary, Compton scattering offers the possibility to produce a quasi monochromatic polarised X/gamma ray beam.

In the presentation, we shall review these kinematical properties and provide illustrative examples.

Applications of Compton scattering

In the presentation, we shall describe the vast domain of applications of Compton scattering. We shall distinguish three kinematical depending on the electron beam energy E_e:

- For E_e ~ 10-50 MeV, X rays of few keV to 100keV are produced. The main application domains are: medical (radiography and radiotherapy), material science, art and palaeontology studies, and pharmacology. In this field, the goal

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is to provide compact electron accelerators that can be located inside an hospital or a museum.
- For E_e ~ 300 MeV, gamma rays of few MeV energy are produced which can be used in nuclear science and nuclear survey.
- For E_e > 1 GeV, high energy photons are produced that can be for electron beam diagnostics (laser wire, polarimeter), to produce polarised positrons and to create high energy photon beams.

We shall describe some of these applications during the presentation.

Optical devices needed for Compton X,gamma rays source

The main drawback of Compton scattering process is its small cross section. It means that one must use special optical amplification schemes in order to reach the X/gamma rates required by the applications described in the previous section.

In the presentation, we shall describe two amplification schemes that use optical resonators (see Fig. 2): the external Fabry-Perot cavity and a recirculation cavity. The expected performance of the external Fabry-Perot cavity system will be described in details.

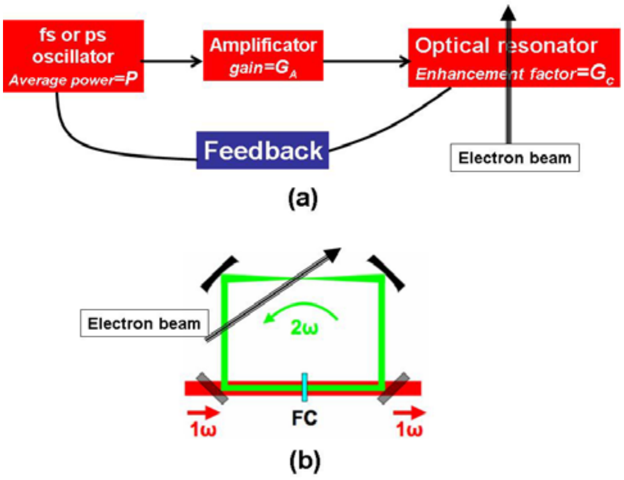

Fig. 2. Two optical scheme used for increasing the laser average power: (a) external Fabry-Perot, (b) Ring cavity recirculation.

Accelerator devices needed for Compton X/gamma ray source

One distinguishes two classes of electron accelerators: the linear accelerators (LINAC) and ring accelerators. Among the LINACs, one further distinguishes those which use supraconducting accelerating cavities for those using warm cavities.

In the presentation, we shall give the advantages and disadvantages of each electron accelerator configurations. We shall also briefly describe the different electron beam dynamics corresponding to these machines.

Status of project/installation

There are presently Compton machines operating in China, Japan and USA. We shall describe these installations during the presentation, as well as the new projects which recently appeared in Europe, Japan and USA.

References Informations

References

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