PROPOSAL OF A SYNCHROTRON RADIATION FACILITY TO SUPPLY ULTRAVIOLET LIGHT, X-RAY, MeV-PHOTON, GeV-PHOTON AND NEUTRON

Y. Kawashima,
JASRI/SPring-8 Accelerator division,
1-1-1 Kouto, Sayo-cho, Sayo-gun, Hyogo 679-5198, JAPAN

Abstract

This is a proposal of new facility, which consists of a 1GeV-linac, a booster synchrotron and a storage ring. The booster synchrotron accelerates electron beam from 1GeV to 10GeV. The storage ring stores the beam at arbitrary energy from 1GeV to 10GeV and top-up operation is carried out at any stored beam energy. The stored beam current depends on the beam energy. In the energy region of 8GeV to 10GeV, maximum beam current is around 100mA. Under the energy of 4GeV, the targeted maximum current is 1A. The storage ring supplies ultraviolet light, MeV-photon, GeV-photon and neutron for solid-state physics, biology, protein structure analysis, drug development and particle physics. The main feature of the facility is to be able to supply the monoenergetic MeV-photon and neutron. With CO2 laser and stored electron beam, monoenergetic MeV-photons are produced through the inverse Compton process. To obtain the targeted monoenergetic MeV-photon, the wavelength of the laser is fixed. On the other hand stored beam energy is changed. Using a superconducting wiggler, a lot of MeV photons are radiated from the wiggler. With the radiated MeV-photon and beryllium target, neutrons are produced. The user can make use of photon and neutron in the same facility.

OUTLINE OF A NEW SYNCHROTRON RADIATION FACILITY

A linac supplies 1GeV electron beam. The beam is transported to a booster synchrotron, which raises the beam energy to an arbitrary energy from 1GeV to 10GeV. A storage ring also stores the beam at an arbitrary energy from 1GeV to 10GeV. To keep the stored beam current constant, top-up operation is carried out at any time. Thus, the booster synchrotron has to equip full-energy injection system. The schematic layout of the new facility is drawn in Fig.1. The maximum stored current over 8GeV is set to be around 100mA, of which value is limited by RF power of beam loading. The targeted maximum beam current is around 1A in the lower energy region under 4GeV. Synchrotron radiation from bending magnets or insertion devices (ID) can be used as an ordinary synchrotron radiation facility. The feature of the new facility is to supply monoenergetic MeV-photon, GeV-photon and neutron [1]. In the next chapters, the methods to produce them are described

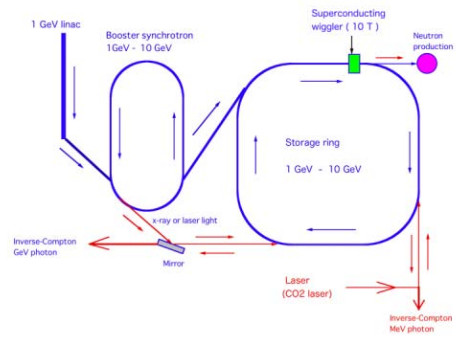

Figure 1: A proposed synchrotron radiation facility consists of a 1GeV-linac, a Booster synchrotron and a Storage ring. A superconducting wiggler with the magnetic field of 10T is installed and supplies MeV-photons to produce neutrons. A collision of CO2 laser and stored electron beam produces MeV-photons through the backward-Compton process. The GeV-photons are also produced with the same process.

MeV AND GeV-PHOTON PRODUCTION

Monoenergetic MeV-photon is produced by backward-Compton process of laser photon. We consider a simple model for the head-on collision of laser light and electron beam. And the scattering angle of the photon is just 180 degrees inverse direction against the laser light. The scattered photon energy E produced by the backward-Compton process is expressed by

$$E(photon) = 4\varepsilon\gamma^2 . \quad (1)$$

Where ε means photon energy of a laser light, γ is the γ factor of beam energy. From equation (1), to obtain MeV-photon of a targeted energy, the wavelength of the laser light or the stored beam energy has to be changed. It is generally normal to change the wavelength of a laser light. However, we know well that it is more difficult to change the wavelength than changing stored beam energy. So we should take easier way. It is very simple way to change the stored beam energy by the current of magnets. We now fix the wavelength of CO2 laser and change the stored beam energy. Calculating photon energy obtained through the backward-Compton process, we can obtain the result as shown in Fig.2. Since the targeted MeV-photons are localized on the axis of just inverse direction against the laser light as shown in Fig.3, we have to extract monoenergetic MeV-photon by using a slit. If scattered photons are extended widely, it is easier to extract them. If the stored beam energy is lower, the dispersion of the scattered photons gets wider. Thus, minimum stored electron beam energy is set at 1GeV.

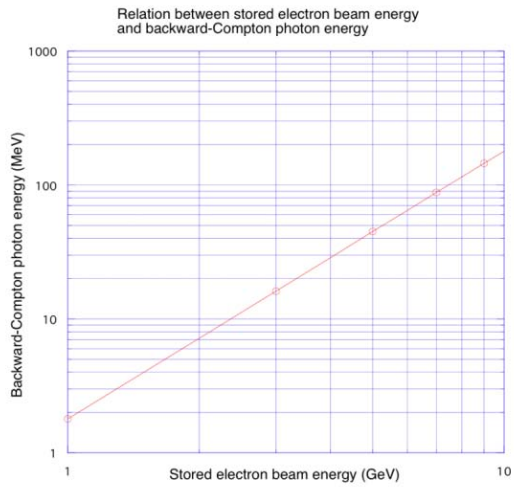

Figure 2: The wavelength (10.6μm) of CO2 laser is fixed and the stored electron beam energy is changed. And a targeted monoenergetic MeV-photon is produced on the axis of just inverse direction against the incident direction of the laser

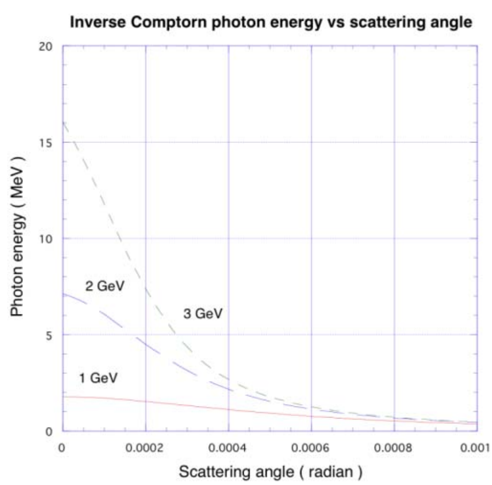

Figure 3: The relation between the energy of inverse Compton photon energy and scattering angle.

To select monoenergetic MeV-photons, we calculated the cross section of the inverse Compton photons and scattering angle. The obtained result is shown in Fig.4. We assume that the distance from an interaction point to a slit is 100m long and the window of the slit is ±1mm. And the acceptance of the scattered photons becomes ±0.01mradian. The energy resolution of the selected photons becomes ±0.14% under the conditions of the stored beam energy of 2GeV. If the stored beam current is 1A at 2GeV and the power of CO2 laser is 1000watts CW and interaction length is 1m and the cross section of the laser beam is 1mm^2, then obtained MeV-photons is ~10^{10}.

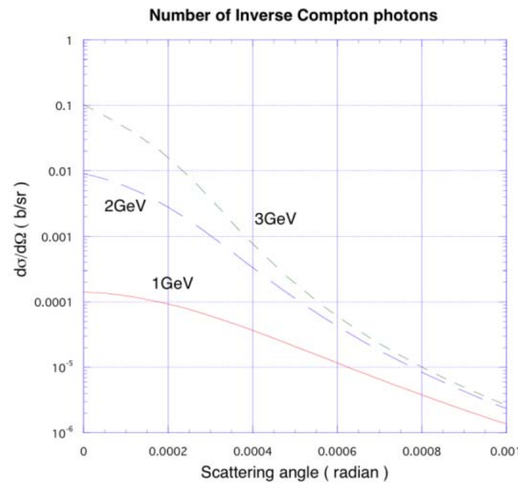

Figure 4: The relation of the cross section and scattering angle.

To obtain GeV-photon through the backward-Compton process, we fix both the wavelength of a laser light and the stored beam energy over 8GeV. The scattered photon energy is measured by tagging a scattered electron. A few lasers are available to produce the GeV-photon. Ar-ion laser with the wavelength of 351nm, for example, is available [2]. To produce GeV-photon, it is preferable that the stored beam energy is larger than 8GeV. So we set the maximum beam energy at 10GeV. To produce GeV-photon, we show another method, which is the head-on collision between the X-ray and stored electron beam as shown in the Fig.1.

NEUTRON PRODUCTION

Neutron is usually produced through hadron interaction process. A new method is introduced here. With beryllium target and MeV-photons produced by a superconducting wiggler installed in a storage ring of the energy more than 8GeV, neutrons are produced through photonuclear reaction process [3]. The most important advantage of the method is not to produce radioactive wastes. We have installed a three-pole superconducting wiggler with the magnetic field of 10T in the storage ring at SPring-8 [4]. With the use of such a superconducting wiggler, we made a simulation to estimate the available number of neutron [5]. A configuration to obtain thermal neutrons is shown in Fig.5 and neutron flux calculated by using a simulation code is also shown in Fig.6. The neutron flux produced by the photonuclear reaction process is one order lower than that of KENS, which is a neutron facility at KEK. To get more neutron flux, we have an idea that the synchrotron radiation is proportional to the 4th power of stored beam energy. Therefore, to obtain more neutrons, it is better to increase the maximum stored electron energy. For example, if the stored beam energy is at 15GeV, the intensity of synchrotron radiation increases around one order of magnitude compared with that of 8GeV.

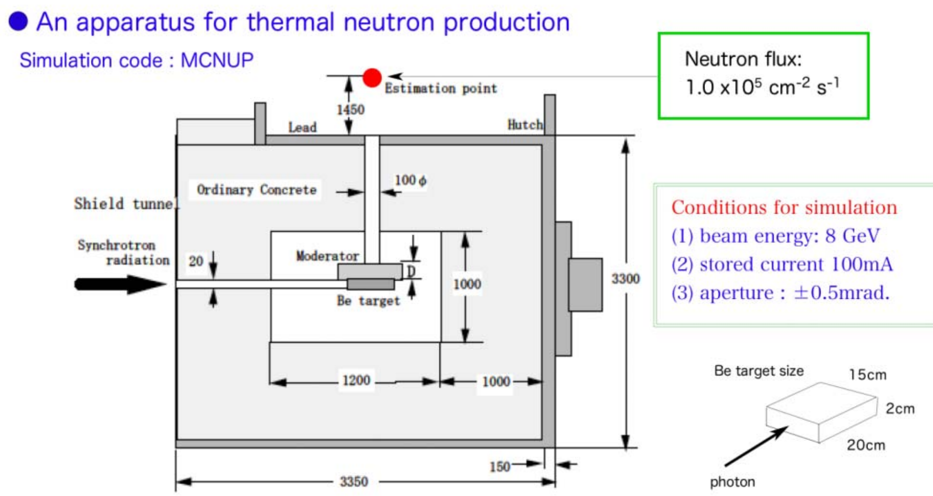

Figure 5: A proposed configuration to obtain thermal neutrons. A block of beryllium target is set up in the center. The most important feature of the method is not to produce radioactive wastes. There is no radiation problem around the apparatus.

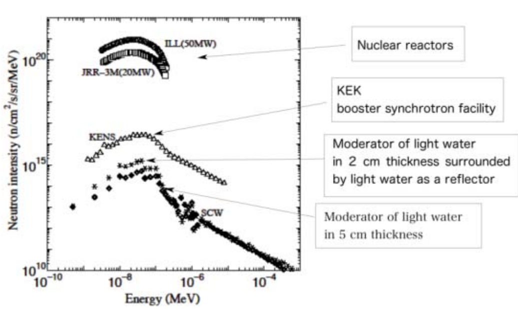

Figure 6: Obtained thermal neutron spectrum and flux.

SUMMARY

A new synchrotron radiation facility proposed here stores the electron beam at an arbitrary energy from 1GeV to 10GeV and the stored beam intensity is kept almost constant by top-up operation. The facility supplies ultraviolet light, X-ray, MeV-photon, GeV-photon and neutron to the scientists of various scientific fields.

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