OVERVIEW OF THE ADVANCED PHOTON SOURCE (APS)*

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Abstract

The Advanced Photon Source (APS) is a state-of-the-art synchrotron light source facility dedicated to the production of extremely brilliant x-ray beams for research [1]. Its super-intense x-ray beams will be used in many areas of research including industrial research, biological and medical research, defense-related research, and basic research. The APS x-ray beams will allow scientists to study smaller samples, more complex systems, faster reactions and processes, and gather data at a greater level of detail than has been possible to date. Creation of these beams begins with electron production by an electron gun with a thermionic cathode. The electrons are accelerated to 200 MeV by a linear accelerator (linac) and then impinge on a tungsten target, resulting in electron-positron pair production. The positrons are accelerated to 450 MeV in the remainder of the linac, then accumulated, damped, and transferred to a synchrotron that increases their energy to 7 GeV. The 7-GeV positrons are injected into a storage ring, where they pass through special magnets that cause them to emit x-rays of the desired quality. Construction at ANL is nearly complete at this time, and the APS will begin operating for users in 1996. The accelerator and experimental facilities are described in this paper, and a brief overview of some of the experimental programs is given.

I. INTRODUCTION

The Advanced Photon Source (APS) is a national materials-science research facility. When the facility is fully operational, as many as 2000 scientists per year from industry, universities, medical schools, and research laboratories, both federal and private, will conduct frontier experimentation at the APS.

X-ray beams are ideally suited to a broad range of applications. Most of what we know about the three-dimensional nature of atoms in DNA, RNA, and viruses has come from x-ray research. Synchrotron x-ray light sources have also allowed scientists to conduct molecular-level examinations of ceramics and semiconductor materials, both of which are essential to the development of designer materials for new technologies.

High-energy particle accelerators were first constructed in the 1940s to enable physicists to study the fundamental laws of nature. Synchrotron radiation was viewed as a problem, as it limited machine performance. It was experimentally studied in 1946, and was observed at the General Electric Research Laboratory's 70-MeV synchrotron. Scientists at Cornell University in 1956 were the first to use synchrotron radiation in experiments. Synchrotron radiation is the electromagnetic radiation emitted by relativistic charged particles moving in a curved orbit, and the radiated power is given by:

$$P = \frac{2}{3}\frac{e^2 c}{\rho^2}\beta^4\gamma^4 \propto \frac{E^4}{m^4} \qquad [1]$$

where e is the electric charge, c is the speed of light, m is the particle's mass, ρ is the orbit radius, and β and γ are the standard relativistic parameters. A typical electron or positron accelerator emits synchrotron radiation in a broad range of photon energies from microwaves to hard x-rays and gamma rays. The use of accelerators as synchrotron light sources has evolved quickly, since accelerators provide electromagnetic radiation in spectral regions for which no other sources of comparable brightness exist, e.g., most of the ultraviolet/soft x-ray range and hard x-rays. As seen from Equation [1], radiated power increases with decreasing mass, thus electrons and positrons that have small masses are used as the radiators in synchrotron light sources. The narrow cone of radiation is directional with an opening angle of $1/\gamma$, and is shown in Figure 1.

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