Workshop 3: Compact X-Ray Sources based on Inverse-Compton Scattering

Schedule of Presentations

Time	Speaker	Affiliation	Title
08:30 - 08:40	Dr. Uwe Arp	SURF III/NIST	Welcome
08:40 - 09:30	Dr. Winthrop Brown	MIT Lincoln Laboratory	Theoretical Background and Performance Optimization of Inverse-Compton Scattering Light Sources
09:30 - 10:20	Prof. Frank Carroll	MXISystems, Inc.	Tunable, Monochromatic X-rays Make Their Medical Debut
10:20 - 11:10	Prof. Ronald Ruth	Lyncean Technologies Inc.	The Compact Light Source: A Miniature Synchrotron Light Source
11:10 - 12:00	Prof. David Moncton	MIT Nuclear Reactor Laboratory	The MIT Inverse Compton X-ray Source Concept: Few Micron Source Size and Sub-Picosecond Pulse Lengths

Abstracts of Talks on following pages

Theoretical Background and Performance Optimization of Inverse-Compton Scattering Light Sources

Winthrop Brown
MIT Lincoln Laboratory

In recent years, inverse Compton scattering light sources have attracted increasing interest as compact and affordable alternatives for high brightness x-ray beam production. With the advent of high average power lasers and ultra-low emittance, high average current electron beams, the possibility of developing such sources with sufficient brightness for demanding applications typically reserved for larger 3rd generation synchrotrons is becoming a reality. In this talk we present an overview of inverse Compton scattering theory and review some of the recent experimental realizations of Compton scattering x-ray sources. Simple scaling relations and numerical simulations demonstrating the dependence of source performance on electron and laser beam parameters are presented, and the pros and cons of different approaches to building high brightness inverse Compton scattering x-ray sources are discussed.

Tunable, Monochromatic X-rays Make Their Medical Debut

Frank Carroll, M.D.
Professor Emeritus, Radiology and Radiological Sciences, and
Professor of Physics and Astronomy
Vanderbilt University Medical Center, and
President and CEO, MXISystems, Inc.

Physicians in the imaging and therapeutic specialties of medicine have long awaited the development of a practical, compact, powerful, inexpensive, robust, safe and easily tunable source of reasonably monochromatic X-rays in a geometry and range of energies that would address previously unmet needs of their clinical colleagues. These needs include: high-contrast low-dose diagnostic examinations, increased lethality for therapeutic radiation beams, molecular imaging and molecular therapy on a meaningful scale.

Uses of these X-ray beams are as diverse as the performance of a new kind of radiation therapy for cancers called Auger Cascade Radiotherapy, and utilization for low-dose 3-D mammography without the use of compression. Additionally, k-edge imaging, phase contrast imaging, time-of-flight imaging, and many military/industrial uses are now possible using these devices.

A third generation patented product, is now being built for placement at several luminary sites for uses in humans and animals, for the purposes of obtaining FDA approval for use throughout the world.

These machines, which are based upon inverse Compton scattering, deliver hard X-rays from 12-100 keV in geometries and fluxes which make them extremely useful in human beings. They produce pulsed 8 ps beams at 10 Hz, and can be tuned to different energies between pulses. They are bandwidth selectable between .01% and 10%, and do not require shielded vaults.

Monochromatic X-ray machines have now truly become a practical medical tool.

The Compact Light Source: A Miniature Synchrotron for the Home Lab

Ronald Ruth
Lyncean Technologies, Inc.

Past research at Stanford Linear Accelerator Center has introduced a new x-ray source concept, a miniature synchrotron light source [1]. This early research led later to the formation of corporation, Lyncean Technologies Inc., which has recently completed development of the Compact Light Source (CLS)[2]. The CLS is a near-monochromatic, tunable, homelab-size x-ray source with up to three beamlines that can be used like the x-ray beamlines at the synchrotrons--but it is about 200 times smaller than a synchrotron light source. The compact size is achieved using a laser undulator and a miniature electron-beam storage ring, in other words--inverse Compton scattering from an electron beam in a miniature storage ring. The CLS is designed to produce a photon flux on sample that is comparable to the flux of highly productive synchrotron beamlines. This presentation will first introduce the basic principles of the Compact Light Source and show how it can bring the quality, tunability and flux of a synchrotron beam line into an x-ray scientist's local laboratory. The construction of the production-prototype CLS, funded by the NIGMS Protein Structure Initiative, is now complete, and the commissioning and testing phase of the CLS prototype is well advanced. The presentation will show details of the storage ring, laser system and x-ray optics, and will conclude with results of the testing of the prototype CLS and x-ray optics.

References

[1] Z.Huang and R.D.Ruth, "Laser-Electron Storage Ring", Phys. Rev. Lett., 80:976-979, 1998.
[2] Supported by the National Institute of General Medical Sciences, the National Institutes of Health, R44 GM665011 and R44
GM074437.

The MIT Inverse Compton X-ray Source Concept: Few Micron Source Size and Sub-Picosecond Pulse Lengths

David E. Moncton
Massachusetts Institute of Technology

The process of inverse Compton scattering, in which an electron of 20-50 MeV backscatters an optical photon into the hard x-ray spectral range, offers the opportunity to produce high-brilliance hard x-ray beams with a laboratory-scale facility. Using a 2-meter superconducting linac and a 1-kW laser system, the time-average brilliance of such beams will be similar to 2nd generation synchrotron facilities. Furthermore, two important characteristics will make our concept unique in comparison to both the best synchrotron sources available today, and the prospective storage-ring based compact sources currently under development. First, beam size can be below 10 microns, and second, the pulse length could be as short as 100 femto-seconds opening up applications difficult or impossible with even 3rd generation sources. This talk will discuss the conceptual design of such a source and the scientific program it could support, including imaging and crystallography in both static and time-dependent modes. Also we will speculate on the possibility of achieving FEL gain in the ICS configuration.