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# Possibilities for Nuclear Photo-Science with Intense Lasers

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## Disclaimer

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The interaction of intense laser light with relativistic electrons can produce unique sources of high-energy x rays and gamma rays via Thomson scattering. "Thomson-Radiated Extreme X-ray" (T-REX) sources with peak photon brightness (photons per unit time per unit bandwidth per unit solid angle per unit area) that exceed that available from world's largest synchrotrons by more than 15 orders of magnitude are possible from optimally designed systems. Such sources offer the potential for development of "nuclear photo-science" applications in which the primary photon-atom interaction is with the nucleons and not the valence electrons. Applications include isotope-specific detection and imaging of materials, inverse density radiography, transmutation of nuclear waste and fundamental studies of nuclear structure.

Because Thomson scattering cross sections are small, < 1 barn, the output from a T-REX source is optimized when the laser spot size and the electron spot size are minimized and when the electron and laser pulse durations are similar and short compared to the transit time through the focal region. The principle limitation to increased x-ray or gamma-ray brightness is ability to focus the electron beam. The effects of space charge on electron beam focus decrease approximately linearly with electron beam energy. For this reason, T-REX brightness increases rapidly as a function of the electron beam energy. As illustrated in Figure 1, above 100 keV these sources are unique in their ability to produce bright, narrow-beam, tunable, narrow-band gamma rays.

New, intense, short-pulse, laser technologies for advanced T-REX sources are currently being developed at LLNL. The construction of a ~1 MeV-class machine with this technology is underway and will be used to excite nuclear resonance fluorescence in variety of materials. Nuclear resonance fluorescent spectra are unique signatures of each isotope and provide an ideal mechanism for identification of nuclear materials. With T-REX it is possible to use NRF to provide high spatial resolution (micron scale) images of the isotopic distribution of all materials in a given object. Because of the high energy of the photons, imaging through dense and/or thick objects is possible. This technology will have applicability in many arenas including the survey of cargo for the presence of clandestine nuclear materials. It is also possible to address the more general radiographic challenge of imaging low-density objects that are shielded or placed behind high density objects. In this case, it is the NRF cross section and not the electron density of the material that provides contrast. Extensions of T-REX technology will be dependent upon the evolution of short pulse laser technology to high average powers. Concepts for sources that would produce 10's of kWs of gamma-rays by utilizing MW-class averagepower, diode-pumped, short pulse lasers and energy recovery LINAC technology have been developed.

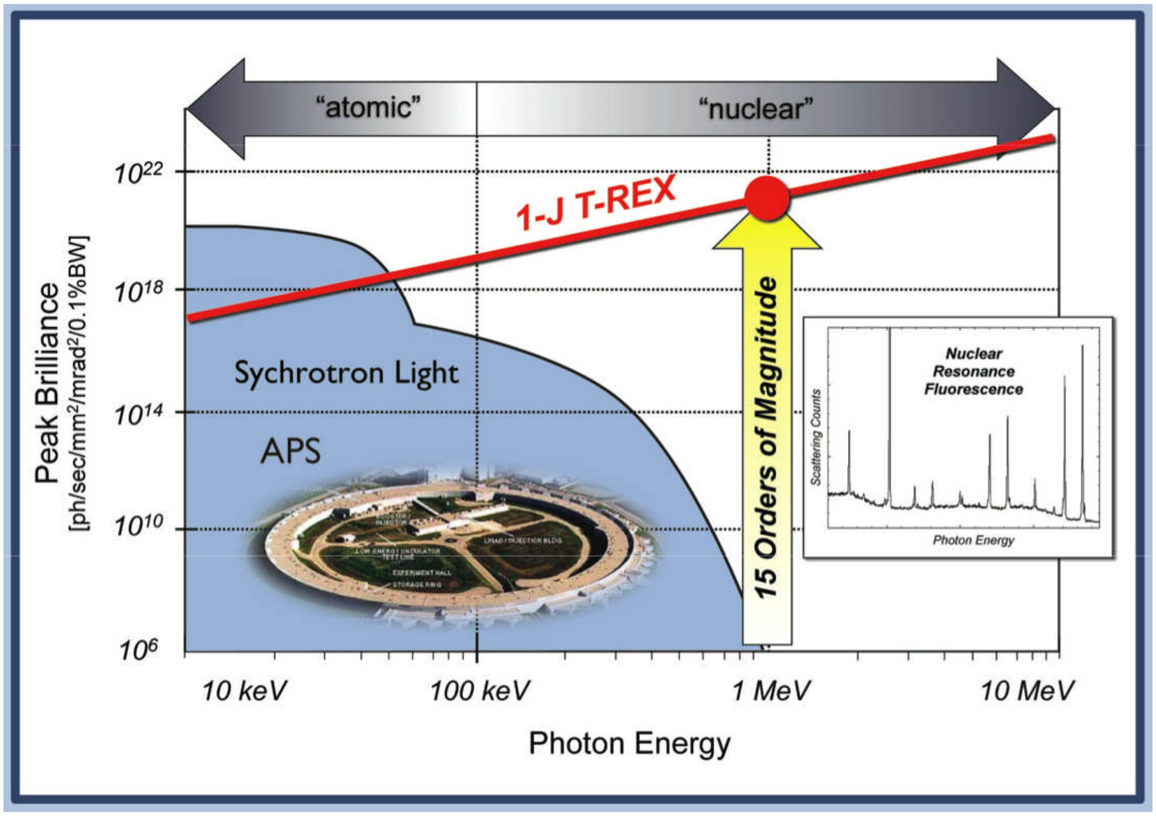


Figure 1. Peak brightness comparison of a 1-J, laser-driven, Thomson-Radiated Extreme X-ray source relative to the output from the Advanced Photon Source, 3rd generation synchrotron at Argonne National Laboratory. At 1 MeV the brightness difference is 15 orders of magnitude. T-REX gamma-ray sources are beam-like with divergence on the order of milli-radians and source size of ~10 microns.

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