Introduction

The operation of the Duke OK-4 storage ring XUV FEL at the Duke Free-Electron Laser Laboratory (DFELL) has presented a new opportunity to nuclear physicists at TUNL and elsewhere. As will be described in detail in Section 2, this new facility, located just 100 feet from the Triangle Universities Nuclear Laboratory on the Duke University Campus, has the potential to produce an intense beam of 100% linearly polarized $\gamma$ rays at energies ranging from about 2 to above 200 MeV, with the current proposal designed to achieve 225 MeV. The new technology, which will produce a $\gamma$-ray flux at least 1000 times as great as anything presently available utilizes an optical klystron - the Duke OK-4 storage ring XUV FEL, a collaborative project of the DFELL and Budker Institute of Nuclear Physics (BINP), Novosibirsk, Russia. Driven by the Duke storage ring, the OK-4 FEL will be capable of generating up to 1000 W of single mode intracavity power with photon energies in the 2-15 eV range. It will be shown that it is possible to run the storage ring in a two-bunch mode whereby the first bunch produces the photons, which, after reflection, backscatter from the second bunch all inside of the optical cavity. This is the distinguishing feature of the proposed facility since it results in uncollimated $\gamma$-ray fluxes in excess of $10^8$/sec/MeV. Simple collimation can be used to produce intense beams of 100% linearly polarized $\gamma$ rays having an energy resolution of better than 1% with energies ranging from 2 to 225 MeV. This proposed High-Intensity Gamma-Ray Source for nuclear physics will be called the HIGS facility [LIT95, LIT96, CAR96].

We have recently succeeded in demonstrating the viability of the proposed technique for producing $\gamma$ rays [LIT97]. Our demonstration run produced a 12.2 MeV beam of $\gamma$ rays by backscattering 379.4 nm (3.27 eV) free-electron laser photons from the 500 MeV electron beam used to produce the photons. We have also demonstrated tunability of the $\gamma$-ray energy varying both the FEL wavelength and the electron beam energy. A description of the results has been published in The Physical Review Letters, and a reprint of this paper is presented in Attachment D of this document. The significance of these results lies in the fact that the measured values of the flux, energy resolution and polarization agreed very well with the calculated values. This indicates that the predictions which will be presented in this paper can be expected to be reliable. This is especially true since our tests indicated the tunability of the beam energy (3 to 16 MeV in this test run), as well as the fact that the "scaling" of the flux as a function of the beam current, $I$, expected to vary as $I^{5/2}$, was indeed the case.

Section 1 of this proposal outlines the impact which beams having the intensity
and quality of those possible at the HIGS facility will have on a broad range of questions in nuclear physics. These include questions involving fundamental symmetries, structure and properties of the nucleons, few-body nuclear systems, pion production in finite nuclei, and reactions significant in the study of nuclear astrophysics. The discussion here is not intended to be exhaustive, but rather to give a flavor of the research directions that would be opened up by the HIGS facility.

A technical description of the HIGS facility will be presented in Sections 2 through 8. A conservative estimate of the performance characteristics of HIGS is assumed in Section 1 for the purpose of evaluating experiments. In particular, it is assumed that the HIGS beam will be 100% linearly polarized and that it will have an energy resolution of 1% or better with a flux of $10^6 \gamma$s per second for energies ranging from 2 MeV up to 225 MeV. It should be noted that these fluxes, at energies above 20 MeV require the upgrade of the storage ring RF system. The full flux of $\gamma$ rays having energies greater than 40 MeV can only be assured after the booster injector is completed, since, at these higher energies, electrons will be lost from the ring as a result of collisions with the FEL photons, and must be replaced at the full beam energy used to create the $\gamma$ rays.