PROGRESS TOWARD A LASER AMPLIFIER FOR OPTICAL STOCHASTIC COOLING

A.J. Dick, P. Piot1, Northern Illinois Center for Accelerator & Detector Development and Department of Physics, Northern Illinois University, DeKalb IL, USA
M.B. Andorf, Cornell University, Ithaca, NY, USA
1 also at Fermi National Accelerator Laboratory, Batavia, IL, USA

Abstract

Optical Stochastic Cooling (OSC) is a method of beam cooling using optical frequencies which compresses the phase space of the beam by correcting the deviation of each particle’s momentum. A particle bunch passing through an undulator produces radiation which is amplified and provides the corrective energy kick. In this project, we are testing a method of amplifying synchrotron radiation (SR) for the eventual use in OSC. The SR is amplified by passing through a highly-doped Chromium:Zinc Selenide (Cr:ZnSe) crystal which is pumped by a Thulium fiber laser. The SR will be produced by one of the bending magnets of the Advanced Photon Source. The first step is to detect and measure the power of SR using a photo-diode. The gain is then determined by measuring the radiation amplified after the single-pass through the crystal. This serves as a preliminary step to investigate the performance of the amplification of beam-induced radiation fields. The planned experiment is an important step towards achieving active OSC in a proof-of-principle demonstration in IOTA.

INTRODUCTION

In the optical stochastic cooling (OSC) scheme, radiation produced by the particle bunch in the pickup undulator will pass through the crystal and be amplified [1, 2]. The amplified radiation is fed back into the kicker undulator and coupled back onto the same beam in such a way to produce a net corrective kick. The process is repeated multiple time in a storage ring leading to a gradual cooling of the beam. With proper lattice design, the cooling can be distributed over all 6-degrees of freedom in the phase space of the beam. The optical amplifier plays a crucial role in the cooling process and the selected amplification medium needs to provide the necessary gain but also provide amplification over a large bandwidth as the cooling time is inversely proportional to the optical-signal bandwidth. One potential lasing medium for the OSC proof-of-principle experiment at Fermilab’s IOTA ring [3,4] is a thin Cr:ZnSe crystal pumped by a thulium fiber laser operating at 1908 nm [5]. The choice of the medium was dictated by its broadband in the mid-infrared which have a large overlap with the undulator radiation emitted from a 7-period undulator [6]; see Fig. 1.

To investigate the amplifier performances, we plan to use synchrotron radiation (SR) produced by one of the bending magnets at the Advanced Photon Source (APS). Specifically, our experiment will be installed in the 35BM beamline hutch. The amplifier setup comprises a Cr:ZnSe crystal which is pumped by a thulium fiber laser operating at 1908 nm. The experiment will guide the final design of the amplifier that will ultimately be incorporated in the active-OSC demonstration in IOTA. The topic discussed in this paper is a continuation of the work initiated in Ref. [7] and aimed at demonstrating amplification of electromagnetic radiation generated by an electron beam at the APS facility.

AMPLIFICATION OF RADIATION

Amplification is produced in the crystal through stimulated emission caused by the broadband SR. The energy levels in the Cr:ZnSe crystal can be modeled as a four-level system. The pumping laser is responsible for populating the third excited state. From there, a radiation-free decay occurs to the second excited state. There are two main processes by which the second excited state falls back to the ground state. It may fall first to the first excited state then to ground or it may fall directly to ground. In the first case, emission from 2 to 1 can be stimulated by the signal SR. Then, like states 3 to 2, the decay from the first excited state to the ground state is radiation-free. In the second case, the wavelength