The LIPSS search for light neutral bosons

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An overview is presented of the LIPSS experimental search for very light neutral bosons using laser light from Jefferson Lab's Free Electron Laser. This facility provides very high power beams of photons over a large optical range, particularly at infrared wavelengths. Data has been collected in several experimental runs during the course of the past three years, most recently in the Fall of 2009.

1 Introduction

There continues to be broad interest in experimental searches for sub-electron volt mass, spin-zero, weakly interacting particles. Searches for non-Standard Model couplings between photons and hypothetical light neutral bosons (LNBs) have been reported by the BMV collaboration [1], the GammeV collaboration at Fermi National Accelerator Laboratory (FNAL) [2] and the OSQAR collaboration at the European Center for Nuclear Research (CERN) [3] and was carried out originally by the BFRT collaboration [4]. These were mainly motivated by the reports in [5] and [6]. The experimental programs that explore the parameter space of weakly interacting, light, spin-zero, bosons by and large all use the light shining through a wall (LSW) technique of photon regeneration [7]; laser photons are sent through a strong magnetic field where some of them can convert into low-mass, weakly interacting bosons. These bosons then pass through a wall that serves to block the incident laser light, and reconvert into photons in a second magnetic field in a similar manner.

The Light Pseudoscalar and Scalar Particle Search (LIPSS) collaboration continues its search for evidence of photons coupling to LNBs in measurements at Jefferson Lab's (JLab's) Free Electron Laser (FEL) facility [8]. Improvements, mostly to FEL optics in order to increase the FEL beam power at 935 nm wavelength, have been made. Additionally, improvements in beam diagnostics such as beam pointing stability and focusing have been achieved during the past year.

2 Experimental setup and data analysis

One of the reasons for using the FEL at JLab is its ability to deliver a high power laser beam in the infrared region. The JLab FEL is capable of delivering more than 14 kW of power at 1.6 micron wavelength. The LIPSS experiment is housed in Laser Lab 1 of the FEL facility. The simplified LIPSS experimental setup is shown in Figure 1. FEL light is sent through an optical transport system to Turning Mirror 1 (TM1) in Lab 1. The beam then passes through a set of adjustable telescopes that collimate its width to approximately six to eight mm in diameter. The beam exits the FEL transport system with essentially 100 per cent linear polarization that can be adjusted for orientation either perpendicular or parallel to the upstream magnetic field region for, respectively, scalar or pseudoscalar boson searches. A polarization rotator is used to achieve this. After TM2, the beam passes the generation magnet volume (GV) where FEL laser photons may couple to a virtual photon from the magnetic field creating a very light neutral boson. The FEL beam then is sent to a beam dump that also functions as a power meter. Any LNBs created will then transverse this optical barrier and enter a second magnetic field region, a regeneration magnet volume (RV) where some may reconvert to real photons. The reconverted photons, having identical properties as the original FEL laser photons, then will be detected by a CCD camera in a light tight box (LTB). Inside the LTB, the beam of photons proceed to TM4, then pass through a Newport- KPX082AR16 50.2 mm lens that serves to focus the beam to one pixel on the CCD array. The CCD camera system is a Princeton Instrument Spec-10: 400BR. This CCD camera system is placed on a translation stage (Newport translation stage model 461-X-M) for easy movement during data taking. The setup also includes a light emitting diode (LED) and a convex lens, used to provide a beam spot on the CCD; this provides a reference on the CCD array. The turning mirrors are RMI mirrors with coatings that are optimized for 935 nm wavelength light. All the mirrors that are in contact with the FEL light are water cooled to minimize power absorption and damage on the mirrors. Irises are used along the beam path for beam alignment. The LTB is a ZARGES aluminum case painted inside with DAP paint. Outside of the LTB, there is a paper box layered with aluminum foil. Inside the LTB, there is also a light tunnel from the AR coated window to the CCD. This tunnel is made from black hutch board to eliminate stray light inside the box. The edge of the LTB is sealed by a rubber liner. Together, this provides a LTB environment that is essentially free of any stray light in Lab 1.

The LIPSS experiment uses IR light because of the report in [5] and because of the special features of the Spec 10:400BR CCD camera, the focusing lens, and AR coated windows. The CCD camera's quantum efficiency (QE) peaks in the visible region of the electromagnetic spectrum, but has a sizeable QE in the near IR region. After optimization, the 900 nm coated high reflector (HR) and output coupler (OR) mirrors resulted in a FEL laser beam centered at 935 nm. The alignment of the FEL beam through the generation magnet is critical for LNB production and detection, in the case that it can take place. Therefore two CCTV cameras monitored TM2 and TM3. The output of the cameras are fed to analog inputs of Spiricon (TM) hardware and software where the beam centroid and spot size can be monitored and recorded. The reference centroid position was determined using FEL alignment mode beam prior to the delivery of high power continuous-wave FEL beam into lab 1 (due to laser safety procedures). During the measurement, the beam positions are automatically adjusted. Prior to the FEL beam delivery, a green laser beam is used to align the turning mirrors, curved mirrors and other optics. This green laser beam is aligned with the FEL alignment mode beam and considered aligned with FEL high power beam. The coincidence of the green laser beam and

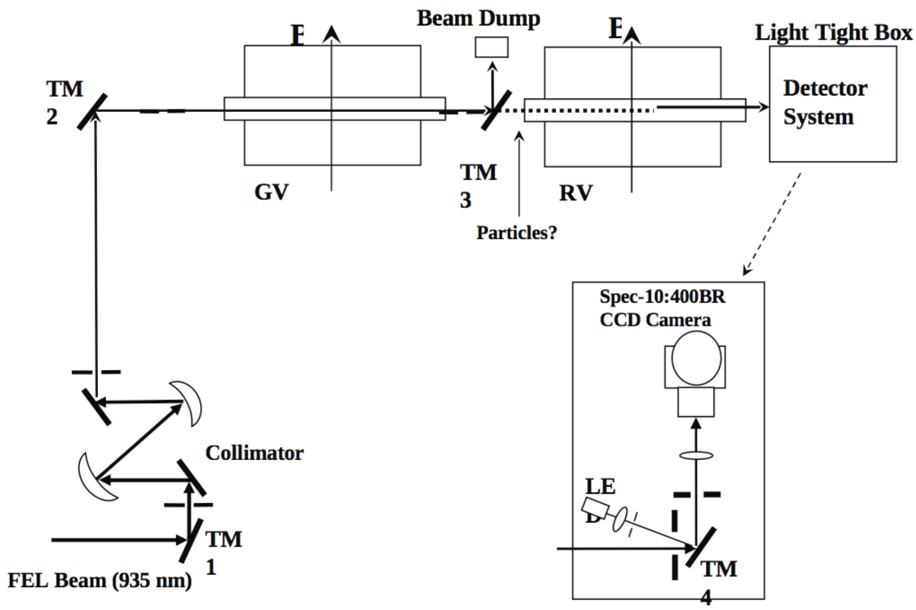

Figure 1: The LIPSS experimental setup.

the alignment mode beam is visually verified along the beam path starting at TM1. The fine adjustment is performed by monitoring the beam image on the CCD while adjusting the translation stage. The position of the one pixel green beam on the CCD is recorded as the center of the region of interest (ROI) in the CCD array. The beam from the LED is collimated first by a plano-convex lens. For easy alignment, the LED and the collimating lens is setup on one stage. A comparison was made between the focused green laser beam (532 nm) and a focused 935 nm light beam from a light source consisting of a Newport Tungsten Halogen Lamp and Oriel Mini Monochromator with spectral range from 500nm to 1.2mm. The light source was set between the two magnets and the light was sent through the vacuum pipe of the regeneration magnet and through the focusing lens without disturbing the beam alignment in the light tight box. There is only a one pixel difference between the center of the expanding 935 nm beam and the x and y positions of the focused pixel from the green laser.

The green laser beam (as well as the alignment mode FEL beam) is also used for testing the pointing stability of a laser beam. The change of the FEL beam position and shape on TM2 and TM3 can be monitored and recorded using spiricon (TM) software as explained above and the beam position is adjusted manually using picomotor controls. In order to ascertain the effect of this change on the ROI around the assigned one-pixel-area, a pointing stability test was performed. The simple test is implemented by moving TM2 horizontally. TM2 in 1 is mounted on a Parker-Daedal translation stage with a 2 inch travel precision micrometer. The green laser beam is focused to one pixel by the focusing lens in front of the CCD. The TM2 positions is varied while recording the counts in a 3x3 pixel area centered at the focused pixel. It was determined that 0.175 inch or 4.45 mm movement was needed in order for there to be a measureable effect comparing neighboring pixels with the in ROI (3 x 3 pixel area). This experimental procedure was implemented for each run that provided results presented in [8].

To summarize, the LIPSS apparatus is performing well. FEL upgrades and installation of a variety of monitors for various parameters have improved the quality of the data. The FEL beam power was increased dramatically in 2009 compared with previous runs. The controls for beam stability on TM2 and TM3 were also improved. New experimental data have been taken as recently as Fall, 2009 and will be presented in a separate paper.

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