➢ Lasers Quantum Optics and Optical Studies of Biomolecules (E, Singh)

Studies of light and light-matter interaction keep generating new ideas and inventions leading to new applications of light. We are interested in both classical and quantum aspects of light and their manipulation in linear and nonlinear optical processes [1-6]. Experimental techniques used in these experiments are applicable to many fields of research in physics, biology, chemistry, and engineering and are ideally suited for involving undergraduate students. Indeed, undergraduate students have been on projects related to all topics mentioned here for almost 25 years in our lab leading to many discoveries, publications and presentations [4-7]. REU student may participate in following experiments

1. Physics of structured light beams: These experiments involve different ways of generating structured light beams and then studying their interference, diffraction, and polarization properties. Two methods for generating structured light beams used in our lab involve (i) design, analysis and building of laser systems to produce structured laser beams and (ii) programming a spatial light modulator to change the spatial phase and amplitude profile (in a plane transverse to the direction of propagation) of an incident light beams. Using these methods, Hermite, Laguerre, Ince-Gauss and many other types of beams can be generated. Student will study their phase and focusing properties and new effects that arise in diffraction and polarization experiments [2-6]. The effects of symmetry of the beam and aperture on diffraction will also be explored. Interest in these aspects is driven by the potential applications of these beams in nano-optics and near field microscopy, and biophysics [8,9].

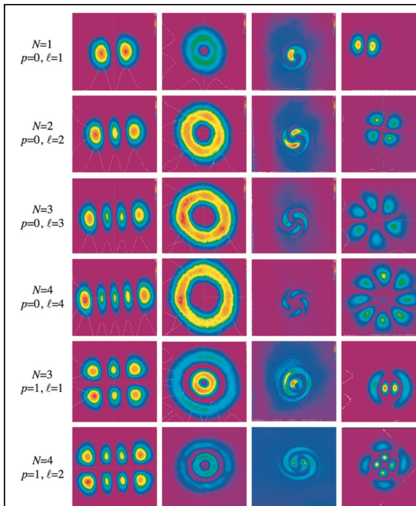

Fig. 8 Experimental Intensity pattern: HG, LG, interference LG with plane wave, and LG with opposite charge. (see Ref. [51])

2. Studies of nanoparticles and biomolecules using dynamical light scattering: The principle underlying dynamic light scattering (DLS) is that light scattered from refractive index fluctuations, which in a solution of nanoparticles or macromolecules, arise from the difference in the solute and solvent polarizability [10-11]. Translational, rotational, and internal motion of molecules change their polarizability in time. This is reflected in the fluctuations of scattered light. By analyzing these fluctuations, it is possible to extract information about the scattering molecules. Thus intensity auto-correlation functions of scattered light and its dependence on scattering angle and polarization can be used to study molecular motion and determine their molecular weight, size, and shape [12]. Several projects that involve determination of the shape (aspect ratio) and/or size of nanoparticles suspended in solution or the chemical complexes formed in two-macromolecule reaction will be available to REU students.

We are also developing a new version of the total internal reflection microscopy (TIRM) where the evanescent wave scattering region is incorporated within a laser cavity [7]. This new technique, which we call iTIRM (for intracavity-TIRM), much larger (typically 50-100 X) intra-cavity power density boosts the strength of the evanescent field for iTIRM by the same factor. This enhancement results in increased scattered from molecules that enter the evanescent wave region. The scattered light then can be analyzed using the techniques of dynamic light scattering.

The students involved in these projects will learn techniques for low level light detection, dealing with noise and fluctuations, physics of laser beams and their manipulation, computer programming using Matlab and Mathematica, data analysis, Fourier transforms, image processing, properties of biomolecules and many experimental and theoretical techniques universally useful in a science and engineering research labs.

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