Announcing the Final Examination of Sudeep Jung Pandey for the degree of Doctor of Philosophy in Physics

Date: **Friday, June 30, 2017**

Time: **8:30 AM**

Room: **PSB 160-161**

Dissertation Title:

"Quantification of non-stoichiometry and impurities in transparent YAG ceramics by laser-induced breakdown spectroscopy (LIBS)"

Abstract:

Transparent ceramics are an important class of optical materials with applications in street-lighting, high-strength windows, electro- and magneto-optical isolators, high-power laser gain media and nuclear radiation detectors. Compared to single-crystal growth, ceramic processing enables size scalability, near net-shape forming and prevents issues associated with dopant segregation and inhomogeneity, such as stress-induced birefringence and wavefront distortions. The fabrication of high optical grade ceramics by route of powder sintering, relies on a controlled set of techniques preventing the formation of scattering centers (pores and secondary phases) and harmful point defects (color centers, charge-carrier trapping sites). This thesis work investigates a novel approach in assisting the fabrication of yttrium aluminum garnet (YAG, $Y_3Al_5O_{12}$) transparent ceramics, an important laser material, and minimizing the presence of these defects. As a line compound in the Al_2O_3-Y_2O_3 phase diagram, YAG has little tolerance for excess of either yttrium or aluminum oxides. What is more, the estimated compositional range of the garnet phase, $(5/3-0.03)<Al/Y<(5/3+0.008)$, which is at the root of fabrication inconsistencies, challenges the sensitivity of most analytical techniques. We have evaluated the use of laser-induced breakdown spectroscopy (LIBS), a rapid, cost effective, non-destructive, and versatile technique, in the determination of stoichiometry and impurities at the various stages of the ceramic fabrication, i.e. in powders, green and sintered bodies. It was found that enough sensitivity and accuracy can be achieved on a custom-built system to discern 0.3 mole percent in the Al/Y ratio. To understand the influence of the plasma temperature on the ratio of the atomic emission lines of Al and Y species, Monte Carlo simulations of YAG-based laser-induced plasmas were performed. The results have guided our experimental protocol by showing that above 12000 K, the Al/Y intensity ratio and thus the sensitivity of the measurement increases sharply with plasma temperature. In addition, we show that LIBS can be used to monitor the concentrations of unintentional trace impurities along those of sintering additives (SiO_2) customarily used for the removal of porosity during firing. Hence, we reveal, for example, that less than 30% of SiO_2 remains in the final ceramic due to evaporation during high temperature sintering.

This work not only extends the range of capabilities of LIBS by showing how highly sensitive quantification of major elements can be performed in insulating materials, but also provides a new set of tools for estimating the range of solid-state solutions in advanced materials and understanding the densification of ceramics. We foresee that such capability will be invaluable for quality control purposes and in areas where fine and reproducible compositional tuning (defect engineering) is needed.

Major: Physics

Educational Career:

B.Sc., Tribhuvan University, 2006

M.Sc., Tribhuvan University, 2010

M.S., University of Central Florida, 2013

Dissertation Advisory Committee Members:

Dr. Romain Gaume (Chair)

Dr. Matthieu Baudelet

Dr. Richard Klemm

Dr. Kevin Coffey

Dr. Stefano Curtarolo

Approved for distribution by Dr. Romain Gaume, Committee Chair, on June 27, 2017

The public is welcome to attend.