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# Ph.D. DISSERTATION DEFENSE

**Candidate:** Abdelali Sajia
**Degree:** Doctor of Philosophy
**School/Department:** Charles V. Schaefer, Jr. School of Engineering and Science / Physics
**Date:** Wednesday, April 30th, 2025
**Time/Location:** 11:00 a.m. / Burchard Room 514
**Title:** Pushing the Boundaries of Resolution: New Methods for Passive Two-Source Superresolution

**Chairperson:** Dr. Xiaofeng Qian, Department of Physics, School of Engineering & Sciences

**Committee Members:** Dr. Yuping Huang, Department of Physics, School of Engineering & Sciences
Dr. Stefan Strauf, Department of Physics, School of Engineering & Sciences
Dr. Zhuo Feng, Department of Electrical and Computer Engineering, School of Engineering & Sciences

## ABSTRACT

Resolving two closely spaced point sources is essential in imaging and sensing. Resolution quality primarily depends on how small a separation can be distinguished and how reliable these distinctions are. Historically, resolution has been constrained by the Abbe-Rayleigh diffraction limit, a practical boundary tied to wavelength and aperture size, making overlapping signals difficult to discriminate by standard intensity measurements. Recent studies have successfully demonstrated super-resolution for two equal-brightness, incoherent sources. Yet, realistic factors like unequal brightness, partial coherence, noise, and signal losses remain critical challenges for practical super-resolution.

As a step towards resolving such issues, we consider the effects of both unbalanceness and a form of partial coherence together by including an entangled partner of the two-point sources. Unexpectedly, it is found that the two negative effects can counter affect each other, thus permitting credible super-resolution, when the measurement is analyzed in the entangled partner's rotated basis.

Second, we explore the superresolution of such two-point sources by examining a special wave property, i.e., entanglement between spatial and remaining degrees of freedom (DoFs), of this composite wave function. Notably, we find that increasing this entanglement enhances the precision of superresolution.

Finally, we present a parameter-decoupled superresolution framework for estimating sub-wavelength separations of passive two-point sources without requiring prior knowledge or control of the source. A physics-informed machine learning (ML) model (trained with a standard desktop workstation), synergistically integrating this theory, further addresses practical imperfections including background noise, photon loss, and centroid/orientation misalignment. The integrated parameter-decoupling superresolution method achieves resolution 14 and more times below the diffraction limit.

Our result represents useful guidance towards the realization of super-resolution for practical point sources.