长春理工大学
Changchun University of Science and Technology

学习计划 STUDY PLAN

基本信息 / Basic Information

姓名/Full Name:

性别/Gender: □Male □Female

年龄/Age:

国籍/Nationality:

层次/Student Category:☐Master student ☐doctoral student

申请专业/Major:

申请研究领域/ Expected Research Area :

入学时间/ Enrollment Date: 2027-09-01

导师签字/Supervisor's Signature:

导师评语/Supervisor's Comments:

签署日期/DATE: 2026-11-06

1. 学术背景/Academic Background

请简要说明本科或硕士学习经历。

Please briefly describe your undergraduate or master's study experience.

2. 攻读博士/硕士动机 Motivation for pursuing a doctoral/master's degree

3. 职业计划 Career Plan

4. 详细学习或研究计划 / Detail Study or Research Plan

详细学习或研究计划计划须有明确的研究选题、参考文献阅读综述、如何开展研究等内容，不少于 1000 字，请参考后附的模版。

The detail study or research plan for graduate students must include a clear research topic, a review of reference literature, and a description of how the research will be conducted, no fewer than 1,000 words, Please refer to the template attached below.

The template pf detail study plan



博士学位研究生学习计划
Study Plan for Doctoral Degree Program

研究课题名称/ Research Title:

Mapping Ultrafast Plasmons with Photoemission Electron Microscopy

By

姓/Surname：XXXXXXXXXXXXX
名/Given name: XXXXXXXXX

申请院（系）/ School Applying for: Department of Physic
申请专业/ Major Applying for : Optics
申请研究领域/ Expected Research Area : Ultrafast Nano-photonics

November 6 , 2026

1. Abstract

The intrinsic optical characteristics of plasmonic oscillators can be dramatically modified by achieving strong interaction between them. The collective oscillation of surface charges on metallic nanoparticles, which is propelled by an optical field, is known as a localized surface plasmon (LSP). Localized surface plasmons (LSPs), which are nonpropagating surface plasmons, can either dephase radiatively by releasing photons again or decay through Landau damping to produce energetic electronhole pairs. The LSP has unique optical properties that go beyond optical diffraction, such as strong near-field enhancement and optical response control at the nanometer scale, and it has a wide range of potential applications in material science, information technology, nonlinear optical systems, optoelectronics, and biochemical sensing.

In this project, we will use ultrafast photoemission electron microscopy (PEEM) to demonstrate the imaging of ultrafast dynamic evolution and control over the spatial distribution of localized surface plasmon (LSP) modes at sub-optical wavelength scales, as well as further investigate the dynamics of the coupled plasmon modes in the metallic nanostructure.

2. Research Basis

2.1 Research Knowledge:

Plasmon resonance has received a lot of interest and has been used extensively in the field of light-matter coupling because of its localized near-field enhancement characteristics and photonic response control at the nanometer size. Recently, plasmon effects in metallic nanostructure arrays have been used to enhance electron yield, and it is well known that the photoelectron yield produced by surface plasmons is directly connected to near-field enhancement and absorption [1]. Ultrafast photoemission electron microscopy (PEEM) has proved immense power in the characterization of surface plasmons and other electronic excitations because it distinctively combines the required spatial and temporal resolution, making it perfectly adapted for 3-dimensional space- and time-coherent imaging of dynamical plasmonic occurrences on the nanofemto scale. The ability to view plasmonic fields developing at the local speed of light on a subwavelength scale with optical phase precision exposes existing phenomena and offers up new avenues for plasmonics study [2]. Thus, PEEM, which is also a technique for characterizing localized surface plasmons, has paved the way for significant breakthroughs made feasible by ultrafast imaging of plasmonic occurrences on the nanometer scale.

2.2 Literature Review:

Research on the ultrafast dynamics of the plasmonic field in individual gold bowtie nanostructures was carried out by combining interferometric time-resolved photoemission electron microscopy with a damped harmonic oscillator model. It was

discovered that the extracted plasmon field first oscillates at the laser field frequency and then evolves towards its eigenfrequency after a few periods of frequency variation due to the conflict between forced and autonomous plasmon oscillation [3]. Guiqi Wang et al. [1] used photoemission electron microscopy (PEEM) to investigate a large multiphoton photoemission enhancement in a single plasmonic Au-heptamer nanostructure, which supports the Fano resonance. By exploiting the high spatial PEEM resolution and performing calculations, their findings show that the photoemission electrons are mainly emitted from the junction area between the lower surface of the nanostructure and the indium tin oxide film on the substrate. Time-resolved nonlinear photoemission electron microscopy (TR-PEEM) images of weakly excited femtosecond SPPs launched from a rectangular trench milled into a flat silver film were recorded. The experimental results show that the overall photoelectron yield is greatly enhanced (typically a 6-fold enhancement compared to that without a 400-nm pulse) in this configuration. The findings complete the underlying physics of two-color PEEM-optimized SPP spatiotemporal imaging [4].

The control of the spatial distribution of localized surface plasmon modes at sub-optical wavelengths in crystalline silver (Ag) micro pyramids grown on a Si(001) surface was demonstrated in [5]. Multiphoton photoemission electron microscopy (mP-PEEM) was employed to image how the plasmonic field distributions vary with the photon energy, light polarization, and phase in coherent two-pulse excitation. It is demonstrated in [6] that the trench structure may function as a 2D-tunable SPP dispersion element by photographing the noncollinear mode with photoemission electron microscopy (PEEM). The experimental results show that directed propagation of SPPs can be controlled by varying the polarization direction of the femtosecond laser, and, more importantly, the actual propagation direction of the dispersed SPPs can be directly obtained by reading PEEM images of SPPs using the noncollinear excited method in an Ag film. The spatiotemporal switching of the SPP field was revealed in [7] using time-resolved photoemission electron microscopy (TR-PEEM), and experimental results show that by properly selecting the amplitude and time delay of the two incident light pulses in the experiment, the extinction ratio of the SPP directional coupler can be substantially optimized. Using obliquely incident time-resolved photoemission electron microscopy (TR-PEEM), an independent spatiotemporal imaging of the out-of-plane and in-plane components of SPP near-fields in a femtosecond light-excited trench was performed in [8], and the experimental results presented provide direct evidence of SPP having the inherent attributes of transverse spin angular momentum.

Therefore, understanding the physics of surface plasmons and related phenomena generally requires a thorough understanding of the spatial, temporal, and spectral distributions of the total electromagnetic field excited within nanostructures and their interfaces, which reflect the electromagnetic modes of excitation, confinement, propagation, and damping [9].

2.3 Motivation

Ultrafast reactions on nanoscale surfaces may be studied using ultrafast low-energy electron pulses [10]. The simultaneous spatiotemporal confinement of intense electron pulses to femtosecond and manometer scales is a subject of significant interest in the scientific world, considering the potential effect of such breakthroughs across a wide range of scientific and industrial applications. For example, in ultrafast electron scattering, nanoscale probes would provide precise mapping of structural dynamics in materials with nanoscale heterogeneity, leading to a better understanding of the effect of boundaries and defects on macroscopic characteristics. On the other hand, progress in this area is primarily constrained by the brightness and size of the electron source [11]. An approach capable of visualizing the ultrafast plasmon with nanometer and femtosecond spatiotemporal resolution is required to monitor and characterize ultrafast plasmons and to investigate techniques for their control. Such capabilities are provided by femtosecond laser-based multiple-photon photoemission electron microscopy (PEEM). PEEM technology is used to examine a sample in a vacuum by producing two-dimensional intensity maps from electrons released from the sample surface, and it may therefore provide visuals of nanostructures with electron resolution. According to reports, PEEM is an appropriate method for imaging confined optical fields created by femtosecond laser pulses. Not only is the study of plasmon evolution gaining attention in the area of ultrafast photonics, but so is the control of the near-field on an ultra-temporal and spatial scale [12].

Figure 1 shows a scheme of the experimental setup used in the study of plasmon evolution [12]. The photoemission electron microscope (IS PEEM, Focus GmbH) with a lateral resolution of better than 40 nm is used to take the image of the LSP. The sample used in this study is a gold bowtie nanoantenna array, which is fabricated by electron beam lithography and a liftoff process. The gold bowtie structure is on top of a conductive indium tin oxide (ITO) film coated on a glass substrate. The scanning electron microscopy image of the bowtie is shown in Figure 1(b).

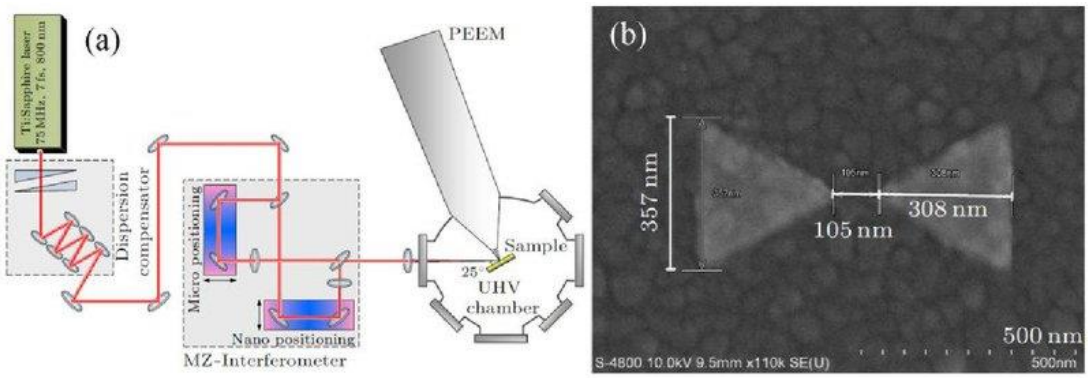


Fig. 1. Schematic diagram of the experimental setup consisting of a femtosecond Ti:sapphire laser system, a dispersion compensator, a high resolution MZ-Interferometer and a UHV-chamber with a PEEM. (b) Scanning electron microscopy image of bowtie nanostructure. Reprinted from [12]

3. Research Proposal

3.1 Research Aim

This proposed study seeks to understand the underlying physics of ultrafast dynamics in nanodevices, which is important for the development of nanodevices in the information field.

3.2 Research Objectives:

The primary goal of this research is to reveal the direct imaging of plasmons on the nanostructure and investigate the physics behind ultrafast plasmon dynamics in the nanostructure using photoemission electron microscopy (PEEM), which will be useful in the development of a nanodevice in the area of information technology. The specific objectives are as follows:

- To properly capture the imaging of the ultrafast dynamic development of the LSP modes on different tips of the nanostructure using PEEM technology based on the detection of local electric field enhancement.
- To actively manipulate the near-field in the region of the nanostructure on an ultra-temporal and spatial scale.
- To perform the simulation of near-field distribution control with commercial software FDTD solutions based on the finite-difference time domain approach (FDTD) in order to investigate the polarization rotation control and coherent control of the plasmon near-field.

3.3 Methodology

The facilities required for this project are already available at Changchun University of Science and Technology, Jilin Province's key laboratory for ultrafast and EUV optics. We will largely employ the existing experimental setup in the physics department to investigate plasmon evolution. Other measurements will be taken at our collaborator's university research facilities. In summary, we anticipate:

a) Fabrication of the sample using electron beam lithography and a liftoff approach [12].
b) Experimental measurements to be carried out with a Ti:Sapphire laser oscillator (Mira 900 Coherent Inc., Santa Clara, CA, USA), which delivered ∼130 fs pulses at an 800 nm center wavelength with a 76 MHz repetition rate and a tunable output wavelength in the 700–900 nm range. The image of the LSP will be taken using a photoemission electron microscope (IS PEEM, Focus GmbH) with a lateral resolution of greater than 40 nm [7], [12].
c) Numerical simulations to be performed using a commercial FDTD package (Lumerical, a unit of Ansys, Inc., Vancouver, BC, Canada) based on the finite-difference time-domain method (FDTD) to reproduce the observed photoemission electron pattern in the PEEM images with both control schemes [8], [12].

4. Discussion

By studying the presented work, we believe the research findings can provide a deep understanding of the underlying physics of ultrafast dynamics in a nanodevice and may pave the way for the development of nanodevices for applications in information technology.

4.1 Tasks Involved in the Research Work

The following are highlights of the tasks involved in the successful completion of this work, and the table below represents the projected duration for each of the stated tasks.

Task A: Survey of the literature on the topic besides a periodic review and a scheduled meeting with the thesis committee members for a discussion on the project, as well as Chinese language studies, which will improve proper teamwork with my colleagues and also communication with the public**.**
Task B: Sample fabrication using electron beam lithography.
Task C: Investigation of the ultrafast plasmon dynamics of the sample.
Task D: Investigation of coherent control of the plasmon near field on the identical nanostructure and imaged with PEEM.
Task E: Analytical and numerical simulations using the FDTD package.
Task F: Writing of comprehensive final thesis report and public oral defense.

4.2 Completion Timeline

Task/Duration	Sep - 23	Oct -23	Nov-23	Dec -23	Jan - 24	Feb -24	Mar -24	Apr - 24	May-24	Sep -24	Oct -24	Nov-24	Dec -24	Jan - 25	Feb -25	Mar -25	Apr -25	Sep -25	Oct -25	Nov-25
Task A																				
Task B																				
Task C																				
Task D																				
Task E																				
Task F																				

References

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