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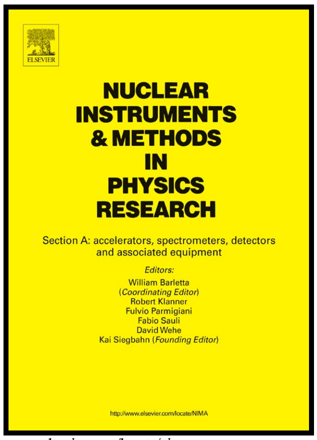

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Surface-Plasmon Enhanced Photoemission of a Silver Nano-Patterned Photocathode

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Abstract

Nano-patterned photocathodes (NPC) take advantage of plasmonic effects to resonantly increase absorption of light and localize electromagnetic field intensity on metal surfaces leading to surface-plasmon enhanced photoemission. In this paper, we report the status of NPC research at UCLA including in particular the optimization of the dimensions of a nanohole array on a silver wafer to enhance plasmonic response at 800 nm light, the development of a spectrally-resolved reflectivity measurement setup for quick nanopattern validation, and of a novel cathode plug to enable high power tests of NPCs on single crystal substrates in a high gradient radiofrequency gun.

Keywords: nano-pattern, surface plasmon, multi-photoemission, silver cathode

1. Introduction

Nano-patterned photocathodes (NPC) have recently received a lot of attention because of their promise for high charge yields, and the possibility to directly use infrared lasers for cathode illumination [1, 2, 3]. A NPC is a photocathode with nano-scale structures on its surface that are responsible for enhanced interaction with incident light of proper wavelength resulting in the excitation of charge density-electromagnetic (EM) field oscillation on the surface. The charge density-EM field oscillation is usually called Surface Plasmon Polariton (SPP). SPPs confine resonant electromagnetic fields on the metal surface and therefore increase the effective laser intensity and electric field by many orders of magnitude, leading to large enhancements in the multiphoton photoemission yield.

With the improvements of nanofabrication techniques, several types of NPCs have been manufactured and tested and up to three orders of magnitude photoemission enhancement has been observed [4, 5]. While NPCs still possess many unexplored opportunities, such as the optimization of the yield enhancement and the generation of higher average current beams. For electron beam tests, copper has so far been the material of choice due to availability and ease of fabrication. However, NPCs need not be limited to copper, as gold, silver, magnesium, niobium and aluminum support SPPs and the nano-structure dimensions can be optimized to achieve very high (better than 90%) laser absorption.

In this study we report on our research on the possibility of improving the yield from NPC using plasmonic materials other than Cu. We optimized the plasmonic response of the nano-structures on a variety of substrates using the finite difference time domain Lumerical simulation code [6]. We then developed a novel imaging spectrometer to independently measure the reflectivity spectrum of the patterns off-line and evaluate the strength of the plasmonic coupling. Experimental photoemission tests were carried out using a silver single crystal wafer which could be inserted in a cathode plug specially designed for the UCLA Pegasus RF gun. Compared to copper NPC, the silver NPC had higher charge yield with a slightly larger emittance.

The rest of this paper is organized as follows: Section 2 describes the optimization of the nano-structures dimensions for several NPC metal substrates. In Sections 3 and 4 we show the experimental measurements on the fabricated silver NPC, which consists of two parts: the off-line reflectivity spectrum measurement and the in-situ high power and electron beam measurements.

2. Nano-pattern optimization

Lumerical FDTD simulations are used to optimize the dimensions of the nanostructures to maximize laser absorption at

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