# SURFACE PLASMON POLARITON GENERATION, PROPAGATION, AND APPLICATION FOR SURFACE ENHANCED RAMAN SPECTROSCOPY

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## INTRODUCTION

The demand for ever increasing data transmission rates and processing speeds is a powerful driver for technologies that combine the unsurpassed bandwidth of optics with the nano-scale integration of electronic circuits. Surface plasmon polaritons (SPP) are electromagnetic surface waves that are not constraint by the optical diffraction limit and therefore hold the potential of merging optics and electronics at the nanometer scales.

For example, in modern computer architectures interconnects are emerging as a major hurdle towards enhanced processing speeds, and signal transmission through plasmon guides has been suggested as a possible route to overcome these limitations.

Another important application of surface plasmons is for Surface-enhanced Raman scattering (SERS) that has attracted considerable attention because it enables accurate identification of exceedingly small sample volumes and even single molecules. However, practical application of SERS has turned out to be very difficult due to its inherent low fidelity (i.e., low reproducibility). It is well known that most of the SERS gain originates from molecules situated at nanoscopic "hot spots," typically formed at junctions between nanosized particles, sharp protrusions or holes, as these are the regions where the electromagnetic field intensity can be enhanced by more than $10^5$ times. Electromagnetic enhancement (EE) is believed to be the primary mechanism responsible for SERS, with chemical enhancement playing a secondary role. Because most SERS gain comes from EE, low fidelity is thought to result primarily from insufficient control over a small subgroup of molecules adsorbed at hot spots that contribute the majority of SERS gain.

The tremendous EE is associated with the excitation of local surface plasmon (LSP) resonances that are confined to the metal nanoparticles, holes, or surface roughness. Another potential source of EE is surface plasmon polaritons. Intensity enhancements due to SPP can reach $10^2$ and are thus significantly smaller than those associated with LSP.

However, their propagating nature allows SPPs to be *focused*, thereby creating an intense spot of near-field optical intensity on a well defined, flat metal surface.

## RESULTS

In our recent work presented here, we show how to efficiently generate and focus SPP, see Figure 1, Ref. 1. We also demonstrate that the focused SPP waves may be guided and delivered elsewhere by using metal strip waveguides, Ref. 2.

Due to the polarization dependence of the focused SPP intensity, a clear observation of plasmon enhanced Raman scattering from Rhodamine 6G (Rh6G) molecules located in the focal spot is possible, see Figure 2. Our experiments introduce a new method for producing a plasmon enhanced Raman active hot spot with potentially improved fidelity, Ref. 3.

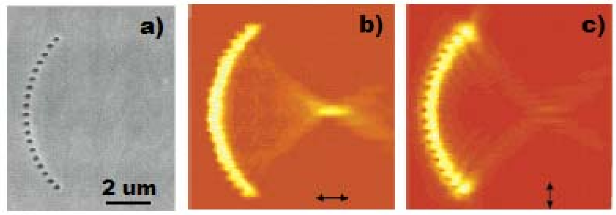


Figure 1. (a) SEM image of a 50 nm thick silver film containing 19 holes arranged on a quarter circle with a 5 µm radius; (b) NSOM image taken in collection mode while the sample was illuminated from the back side at 532 nm incident wavelength and horizontal polarization. The quarter circle source geometry produces "focused" SPP intensity at the center of the circle is clearly seen. (c) NSOM image taken for vertical incident light polarization. The intensity at the focal point is strongly reduced.

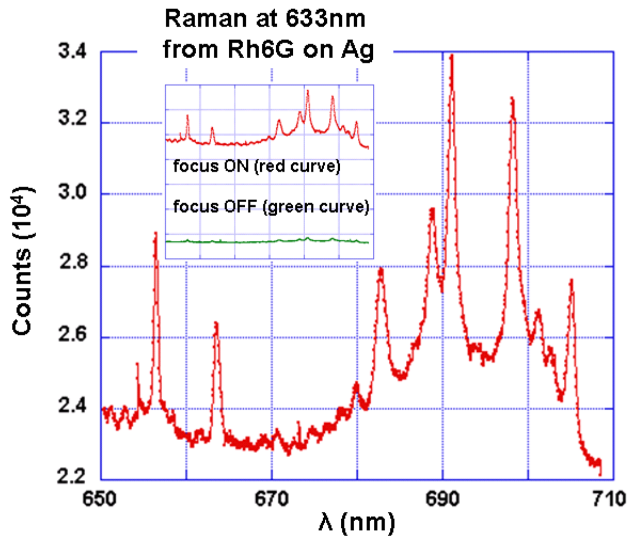


Figure 2. Raman spectrum of the biomolecule Rhodamine 6G as collected from the focal point of a plasmonic lens similar to the one introduced in Fig.1. Rotating the polarization of the incident light by 90° turns the focusing effect ON and OFF, corresponding to increased and reduced Raman signal intensity.

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