# Generation of surface plasmons by electron beam excitation

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We report on the first demonstration of excitation of propagating surface plasmon polaritons (SPPs) by injection of a beam of free electrons on an unstructured metal interface, providing a highly localized and intense source of plasmon waves. The plasmons were detected by a grating-assisted decoupling into light at a set of distances from the excitation point. This technique allows the high-resolution mapping of plasmon and photon emission from metal nanostructures.

The SPPs were excited in 200 nm thick gold films by the 50 keV electron beam of a scanning electron microscope (SEM). The SPPs were outcoupled into light by a 50 nm deep grating of 300 nm period, with the outcoupled light collected by a fibre bundle into an optical spectrum analyzer (Fig. 1, left). The peaks of the collected spectra well correlate with predicted peak positions of maximum plasmon outcoupling efficiency (Fig. 1, middle).

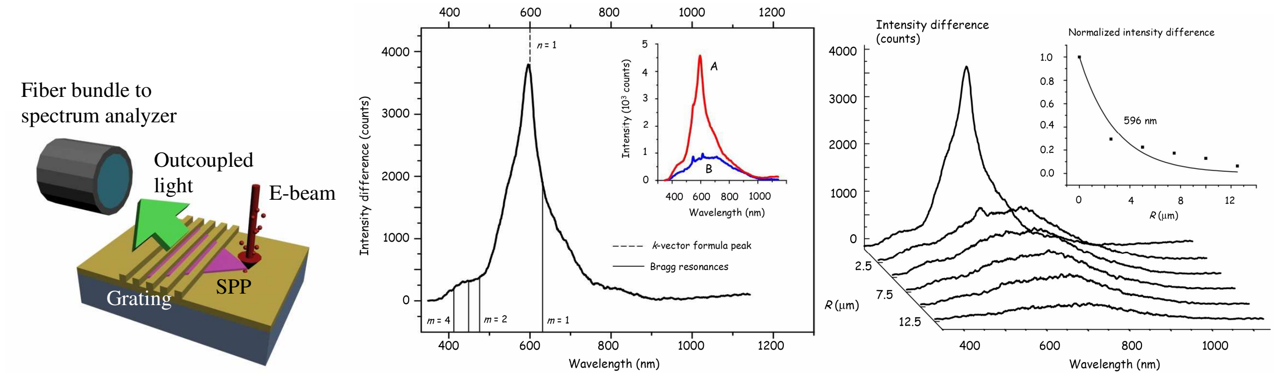


**Figure 1.** The experimental setup in electron beam excitation of SPPs on a planar surface (left), and the differential spectrum of SPPs outcoupled from the grating (middle). Theoretically predicted peaks for maxima of outcoupled radiation are indicated by dashed lines, and the inset shows the emission spectrum of (A) excitation at the grating and (B) excitation at an unstructured area far away from the grating. The differential spectrum is obtained by subtracting spectrum B from spectrum A. The graph to the right shows the dependence of the distance *R* between the excitation point and the grating.

As the point of excitation is moved away from the grating, the SPP component of emission diminishes due to attenuation (Fig. 1, right). Different parts of the outcoupling spectrum decay with different pace due to the dispersion of the plasmon decay length in gold. As an estimate of the power of the SPP source, a beam current of 10 μA creates a source of about $6\times10^9$ SPPs per second,[1] corresponding to a few nano-Watts of the source power. By simultaneously recording electron beam position and spectrum from the sample, one obtains spatial maps of the spectra of photon and plasmon emission from any metal nano-scale sample with resolution down to 5 nm. These maps reveal plasmon propagation paths, regions of propagating plasmon and photon emission, and the structure of generated plasmon modes. In addition to the gold gratings, we also studied electron-beam generated SPPs in aluminium films.

In conclusion, we have shown that the electron beam excitation of an unstructured gold surface provides an intense localized source for propagating surface plasmons. This may be the technique of choice for the creation of high-resolution plasmon and photon emission maps, high density of plasmons necessary for demonstrating nonlinear regimes of SPP propagation, and achieving a high-density of plasmons in the active media of SPASER.

1. M. V. Bashevoy, F. Jonsson, A. V. Krasavin, N. I. Zheludev, Y. Chen, and M. I. Stockman, Nano Lett. **6**, 1113 (2006).