Broadband Line Imaging with Subwavelength Resolution Using Plasmonic Waveguides

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In this paper we design a high-resolution line imaging device allowing for broadband operation at near-infrared wavelengths ranging from 1 μm to 2 μm utilizing the advantage of subwavelength light confinement in plasmonic waveguides. The device consists of an array of air-guided plasmonic waveguides in gold with fanned-out geometry (see Fig. 1a) [1]. In the main part of the device the separation between waveguides increases gradually from the input towards the output. High resolution is achieved on the input side by tapering down the periodicity between channels to 150 nm, while simultaneously maintaining propagation losses of a few dB. The proposed design also minimizes optical cross-coupling between waveguides; each channel thus transmits optical fields independently allowing for high signal-to-noise ratio imaging. At the low-resolution side properly tailored output couplers are designed to enhance optical coupling to free space. This is also shown to be an effective method to reduce back reflection, thus minimizing Fabry-Pérot effects in the waveguides and allowing for broadband operation.

The imaging capacity of the device is demonstrated using finite-element simulations (see Fig. 1a). The numerical model shows that up to 90% of the light from two closely spaced point dipole emitters can be coupled into the corresponding waveguides on the high-resolution side and can be transmitted to the low-resolution side with moderate losses and low cross talk. Thus, two point dipole sources separated by 150 nm can be effectively distinguished by such a device. Moreover, consistent operation in the whole wavelength range from approximately 1 μm to above 2 μm is demonstrated. Fig. 1b shows total losses of each channel calculated for a set of wavelengths. At wavelengths near 1 μm the loss increase is caused by gold material absorption, while at wavelengths above 2 μm cross-coupling between channels limits the device performance. For the proposed device dimensions (shown in the inset in Fig. 1b), the array can contain up to 19 channels, which is limited by cross-coupling and losses caused by sharp channel bending.

Exhibiting large coupling efficiency and moderate transmission losses, the device allows for imaging of weak sources with a resolution of 150 nm over a broad bandwidth in the near-infrared range. This device can be effectively applied as a high-resolution linear image detector or, by operating in the reverse, for high-resolution optical writing.

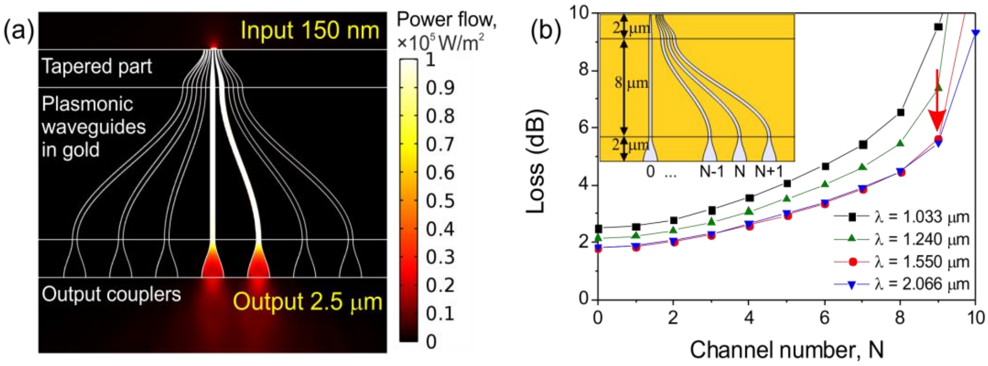

Fig. 1 (a) Optical power flow inside the plasmonic waveguides excited by two incoherent point dipole sources emitting at 1.55 μm and separated by 150 nm. (b) Propagating loss of each channel for wavelengths between 1 μm and 2 μm. Inset shows the device dimensions.

References

[1] N. Podoliak, P. Horak, J. C. Prangsma, and P. W. H. Pinkse, *IEEE J. Quantum Electron.* Vol. 51, 7200114 (2015).