Supporting Information

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Mode analysis

The coaxial nanoaperture was designed to support a single plasmonic transverse magnetic (TM) guided mode with an OAM of $l_{GM} = \pm 1$. Its E_z field distribution is given in general as,

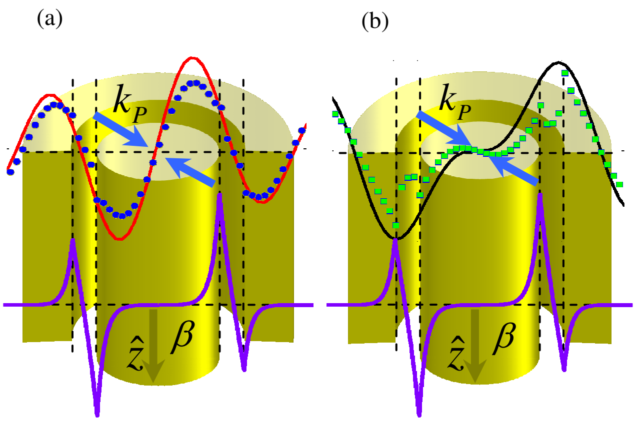
$$E_z^{GM}(\varphi, r) = \exp(i l_{GM} \varphi) \begin{cases} A K_{l_{GM}}(a_2 r) & cladding \\ B I_{l_{GM}}(a_1 r) + C K_{l_{GM}}(a_1 r) & air\ gap \\ D I_{l_{GM}}(a_2 r) & core \end{cases}, \quad \text{(SI1)}$$

where (r, φ, z) is the cylindrical coordinate set, $a_\alpha = \sqrt{\beta^2 - \varepsilon_\alpha k_0^2}$, ε_α is the dielectric constant ($\alpha = 1$ for the air gap and $\alpha = 2$ for the metal), β is the guided mode propagation constant along the z axis, and $k_0 = 2\pi/\lambda_0$ is the wavenumber of the incident light. I and K are modified Bessel functions of the first and the second kind, respectively.

The plasmonic surface modes of a circular structure were previously analyzed in ref. 18. The electric field is given by

$$E_z^{SM}(\varphi,r) \propto [\exp(il_{SM}\varphi)]\boldsymbol{J}_{l_{SM}}(k_p r)\ . \text{(SI2)}$$

The notation $\boldsymbol{J}_l$ stands for the lth-order Bessel function of the first kind, and the plasmonic in-plane wavenumber is given approximately by $k_p \sim k_0\sqrt{\varepsilon_2/(1+\varepsilon_2)}$. In order to excite the desired guided mode, the field distribution of the surface mode has to overlap with the guided mode in the aperture. This is achieved when the AM selection rule is satisfied. When a spiral corrugation (l_S = 2) is illuminated with circularly polarized light, the orbital angular momentum of the surface mode can be either l_{SM} = 1 or l_{SM} = 3. The E_z of the surface modes for both cases, along with the guided mode E_z field distribution, were calculated by Finite Difference Time Domain (FDTD) algorithm. The theoretically predicted E_z distribution (Eq. (SI2)) is presented next to the FDTD calculated one for each case. Obviously, the best overlapping of the surface and guided modes is obtained for the $|\sigma_-\rangle$ incident illumination, i.e. when l_{SM} = 1 (SI, Fig. 1), while both of the modes undergo a π-phase change inside the aperture.



Supporting Figure 1. Comparison of the surface and the guided mode E_z field distributions. (a) theoretical (red solid line) and calculated (blue circles) E_z component of the surface mode excited by the spiral corrugation ($l_S = 2$) with $|\sigma_-\rangle$ incident beam. (b) theoretical (black solid line) and calculated (green squares) E_z component of the surface mode excited by the spiral corrugation with $|\sigma_+\rangle$ incident beam. Violet solid line represents E_z distribution of the guided mode.