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Optimization of Plasmonic Structure Integrated Single-Photon Detector Designs

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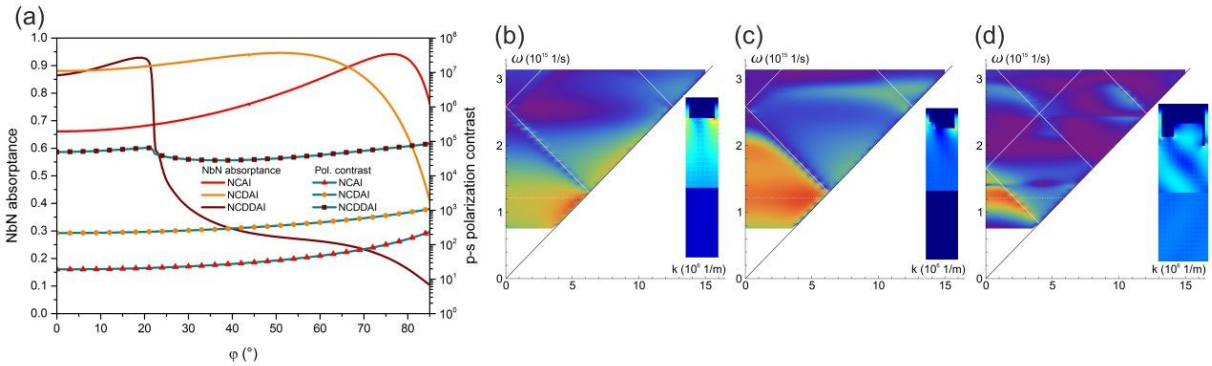
Superconducting nanowire single photon detectors (SNSPD) are devices to detect infrared light up to single-photon resolution with high speed. Plasmonic structures integrated into SNSPDs are capable of enhancing absorptance along with the reduction of kinetic inductance. Nano-cavity-array (NCAI), nanocavity-deflector-array (NCDAI) and nano-cavity-double-deflector-array (NCDDAI) were integrated around meandered pattern of 4 nm thick niobium-nitride (NbN) superconducting stripes [1, 2]. To find the optimal plasmonic structure integrated SNSPD configurations resulting in maximal NbN absorptance for p-polarized 1550 nm light illumination the built in algorithms of COMSOL were used, and all geometrical parameters as well as the illumination direction were varied.

The highest p-polarized absorptance was achieved in S-orientation (γ=90° azimuthal angle) of all integrated SNSPDs. The highest 94.2% absorptance was attained in half-wavelength-scaled periodic NCAI-SNSPD at 76.4° tilting corresponding to the plasmonic Brewster angle. In half-wavelength-scaled NCDAI-SNSPD plasmonic pass bands appeared, and the highest 94.6% absorptance was attained at 50.7° tilting due to reflectance suppression. In NCDDAI-SNSPD three-quarter-wavelength-scaled pattern results in the largest 92.9% absorptance at 18.9° tilting due to first-order grating coupling.

In the optimized configurations the spectral sensitivity and dispersion characteristics were investigated of all integrated SNSPD devices. The optical response for s-polarized light illumination was also inspected, and the achievable polarization contrast was determined. Finally the illumination direction and spectral sensitivity of the polarization contrast was examined, which is a crucial property of SNSPDs in quantum communication and cryptography. In conclusion: half-wavelength-scaled deflector arrays promote to reach larger absorptance, while three-quarter-wavelength-scaled double deflectors make possible to enhance polarization contrast considerably.



(a) NbN absorptance and polarization contrast as a function of φ polar angle in integrated SNSPDs optimized by COMSOL. Dispersion relation of the optimized (b) NCAI-, (c) NCDAI- and (d) NCDDAI-SNSPD. Time-averaged **E**-field with power-flow arrows at maxima are depicted as insets.

[1] M. Csete, A. Szalai, Á. Sipos, G. Szabó: Optics Express **20**/15, 17065-17081 (2012)

[2] M. Csete, Á. Sipos, A. Szalai, F. Najafi, G. Szabó. K.K. Berggren: Scientific Reports **3**:2406 (2012)

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