Optimized Illumination Directions of Single-photon Detectors Integrated with Different Plasmonic Structures

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Introduction:

Optimal orientations of different superconducting nanowire single-photon detector (SNSPD) designs were determined by COMSOL. Absorption of niobium-nitride (NbN) stripes in two different (p=220 nm, 3p=660 nm) periodic patterns was computed. The NbN absorptance was enhanced via integrated plasmonic structures: reflectors, nano-cavity-array, deflectors. Idea: application of double resonance condition.

Results:

Optical responses and near-field distribution in p=220 nm, and 3p=660 nm integrated SNSPD designs were determined.

The 3D (b) insets show the dual-angle-dependent NbN absorptance.

Methods:

Both polar and azimuthal angles were swept during p-polarized illumination in conical-mounting.

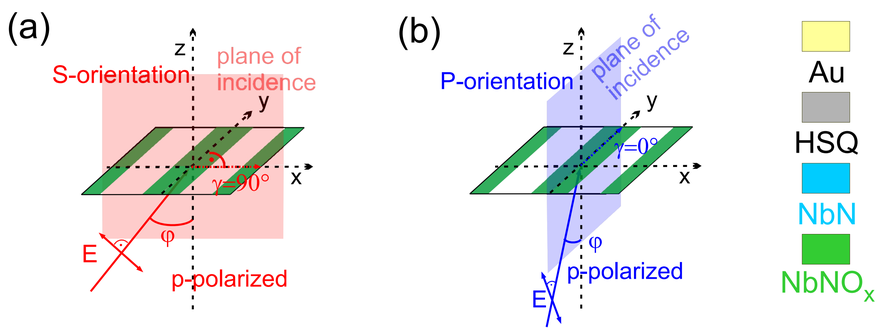

Fig. 1. Two specific orientations studied in more details are: (a) S-orientation (γ=90°), (b) P-orientation (γ=0°).

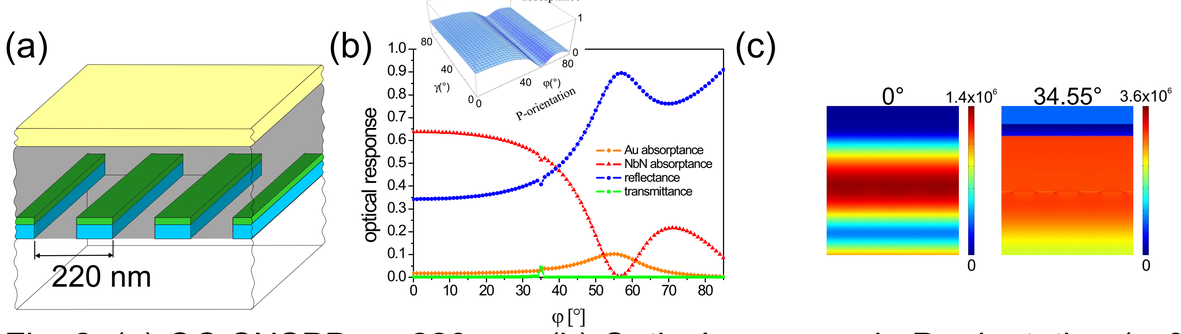

Fig. 2. (a) OC-SNSPD, p=220 nm. (b) Optical response in P-orientation (γ=0°). (c) Normalized E-field at extrema.

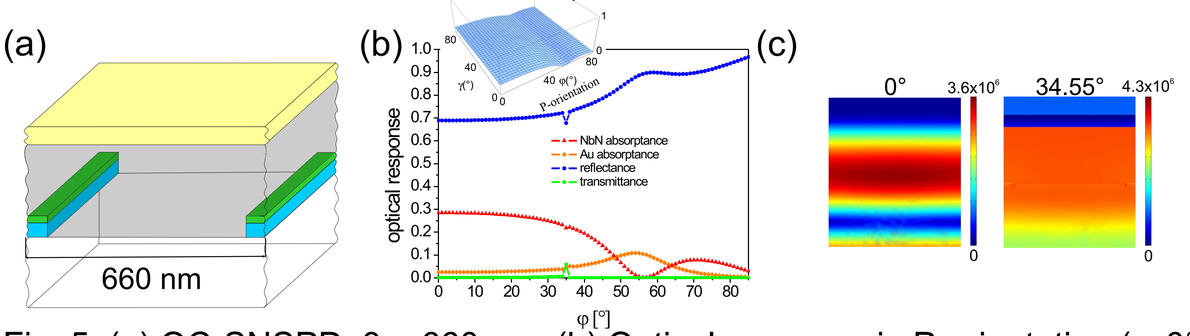

Fig. 5. (a) OC-SNSPD, 3p=660 nm. (b) Optical response in P-orientation (γ=0°). (c) Normalized E-field at extrema.

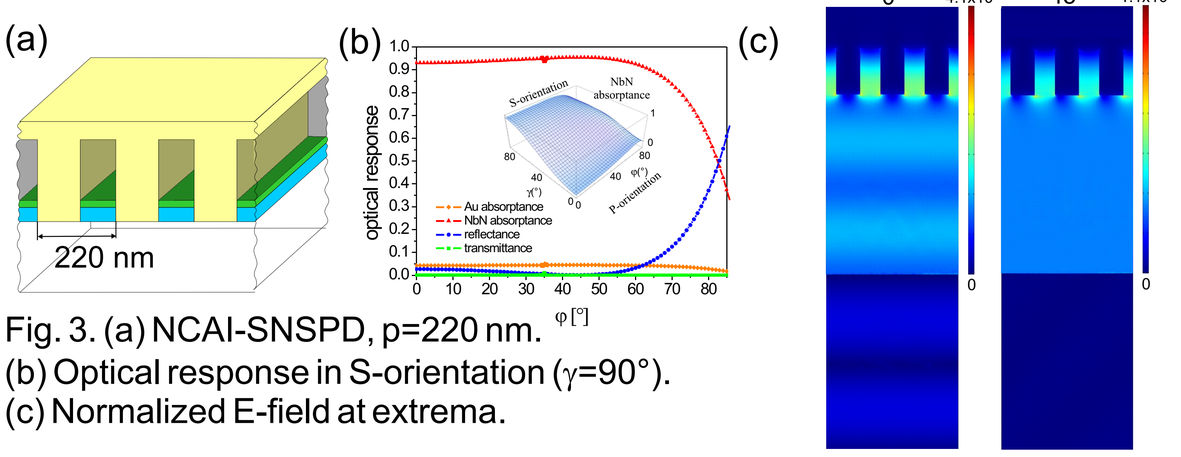

Fig. 3. (a) NCAI-SNSPD, p=220 nm.
(b) Optical response in S-orientation (γ=90°).
(c) Normalized E-field at extrema.

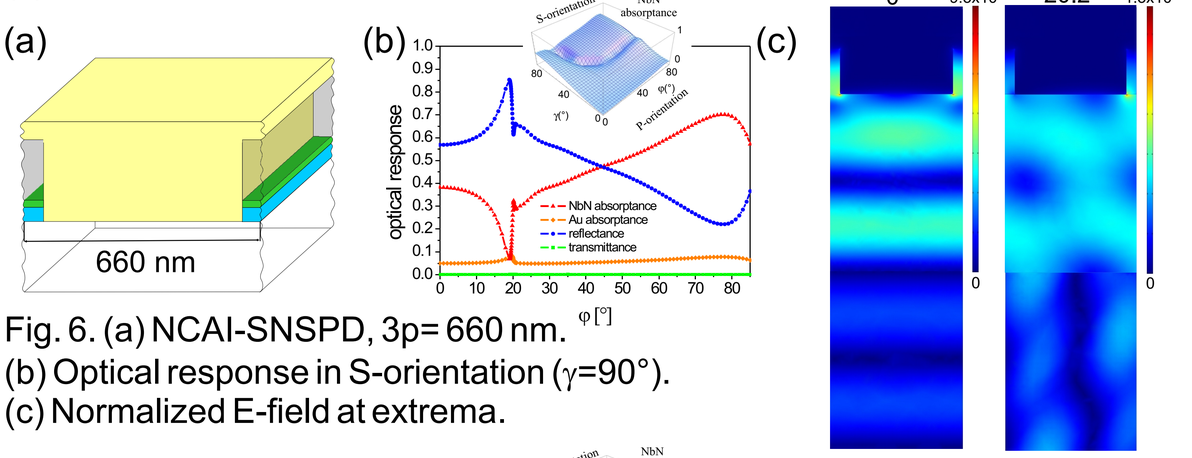

Fig. 6. (a) NCAI-SNSPD, 3p= 660 nm.
(b) Optical response in S-orientation (γ=90°).
(c) Normalized E-field at extrema.

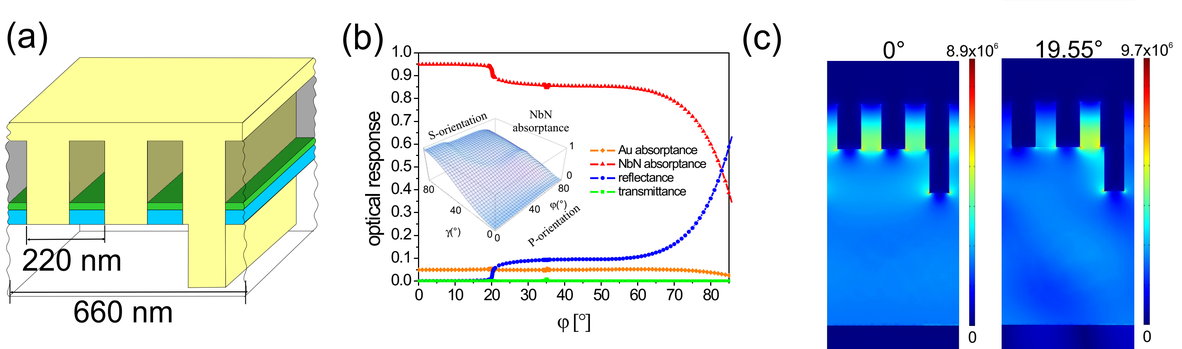

Fig. 4. (a) NCDAI-SNSPD, p=220 nm, with additional deflector having a period of 3p= 660 nm.
(b) Optical response in S-orientation (γ=90°).
(c) Normalized E-field at extrema.

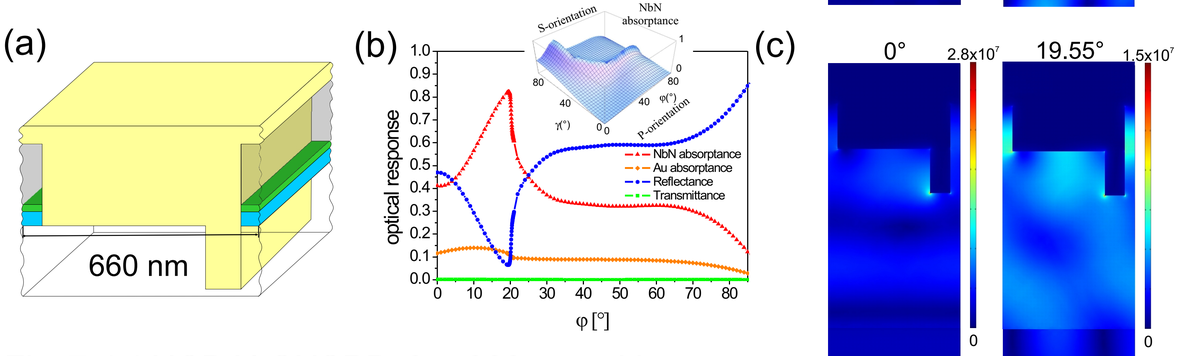

Fig. 7. (a) NCDAI-SNSPD, 3p=660 nm, with additional deflector having the same 3p periodicity.
(b) Optical response in S-orientantion (γ=90°).
(c) Normalized E-field at extrema.

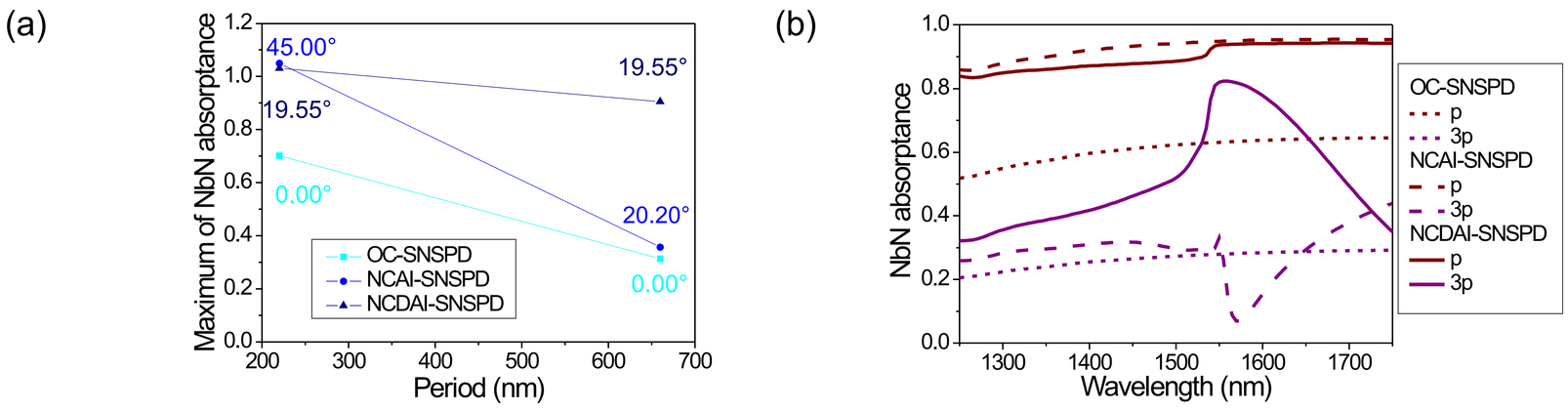

Fig. 8. (a) Normalized absorptance in p and 3p-periodic SNSPD designs
(b) Wavelength dependent absorptance at the orientations indicated in (a).

Conclusions:

OC-SNSPD: optimum direction is perpendicular incidence onto NbN stripes in P-orientation,
NCAI-SNSPD & NCDAI-SNSPD: improved absorptance is attainable in S-orientation,
NCAI-SNSPD, p=220 nm: almost polar-angle-independent perfect absorptance,
NCAI-SNSPD, 3p=660 nm: surface waves result in absorptance enhancement,
NCDAI-SNSPD, 3p=660 nm: illumination at φ corresponding to double resonance condition compensates three-times lower fill-factors due to E-field enhancement via plasmonic modes resonant in nano-cavities and propagating below NbN stripes.

References
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