Characterization of the Tunable Mid Infrared Photon Pair Source realized in the nonlinear $AgGaS_2$ medium

F. Krajinic[1, 2], I. Firez[1], M. Lazic[1], S. Beric[3], M. Curcic[2], M. Lekic[2], B. Jelenkovic[2]

[1]University of Belgrade, School of Electrical Engineering, Belgrade, Serbia
[2]University of Belgrade, Institute of Physics Belgrade, Belgrade, Serbia
[3]University of Belgrade, Faculty of Physics, Belgrade, Serbia

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Abstract

In our work, we built a setup for SPDC within the AGS crystal in the type-I configuration using a pump at the 660 nm wavelength. By angle tuning the phase matching condition of the bulk AGS crystal, we are able to generate idler photons in the fingerprint region from 5.6 µm up to 10.9 µm. Corresponding signal wavelength from 747 nm to 703 nm was measured with a scientific complementary metal-oxide-semiconductor camera and with a fiber-coupled spectrometer. Signal photon count as a function of pump optical power confirmed the low gain regime of the SPDC. The maximum brightness of the AGS photon pair source was calculated to be $3*10^4$ kHz/mW. In pursuit of building a future quantum imaging system in the mid infrared region, we also characterized the signal beam properties for different pump beam radii to achieve quantum microscopy resolution limited by the diffraction limit of the idler photons.

Theory and Simulation

- Spontaneous parametric down-conversion (SPDC) - second order nonlinear process
- Birefringent nonlinear medium - silver-gallium-sulfide ($AgGaS_2$)
- Phase matching condition

$$\Delta k = \frac{2\pi n_e(\lambda_p,\theta)}{\lambda_p} - \frac{2\pi n_o(\lambda_s)}{\lambda_s}\cos(\beta_s) - \frac{2\pi n_o(\lambda_i)}{\lambda_i}\cos(\beta_i)$$

$$0 = \frac{2\pi n_o(\lambda_s)}{\lambda_s}\sin(\beta_s) - \frac{2\pi n_o(\lambda_i)}{\lambda_i}\sin(\beta_i)$$

- Joint spectral probability

$$I \propto sinc^2\left(\frac{\Delta k L}{2}\right)$$

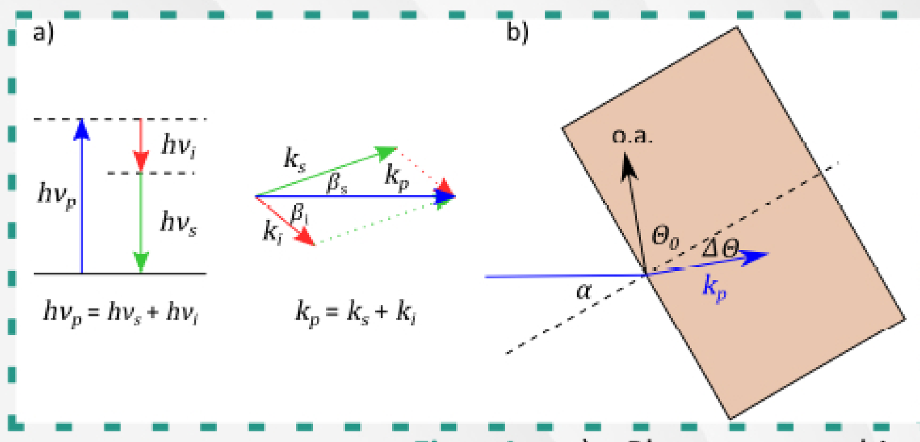

Fig. 1: a) Phase matching condition. b) Pump propagation in the AGS crystal.

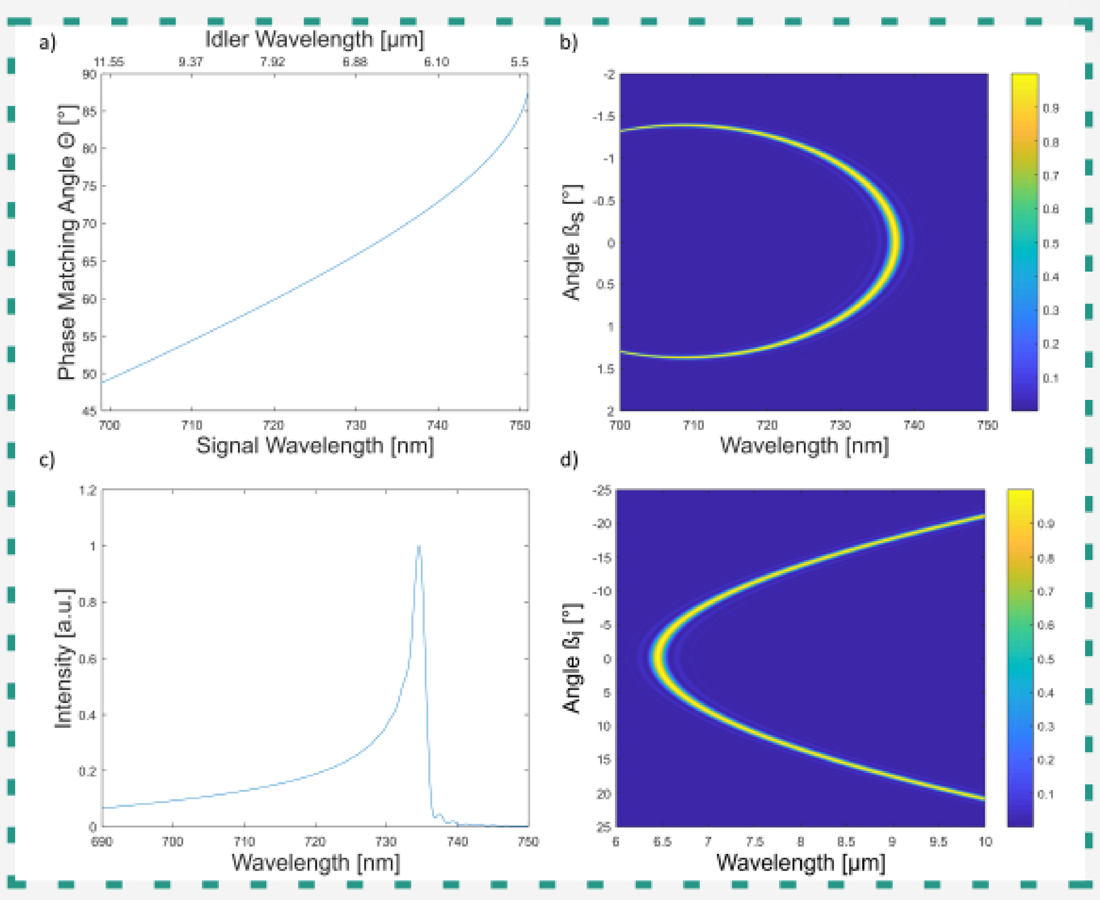

Fig. 2: a) Phase matching condition for the AGS crystal in type-I configuration. b) Frequency angular spectrum for the signal photons. c) Spectrum of the signal photons collected with the numerical aperture of 0.0875. d) Frequency angular spectrum for the idler photons.

Experimental Results

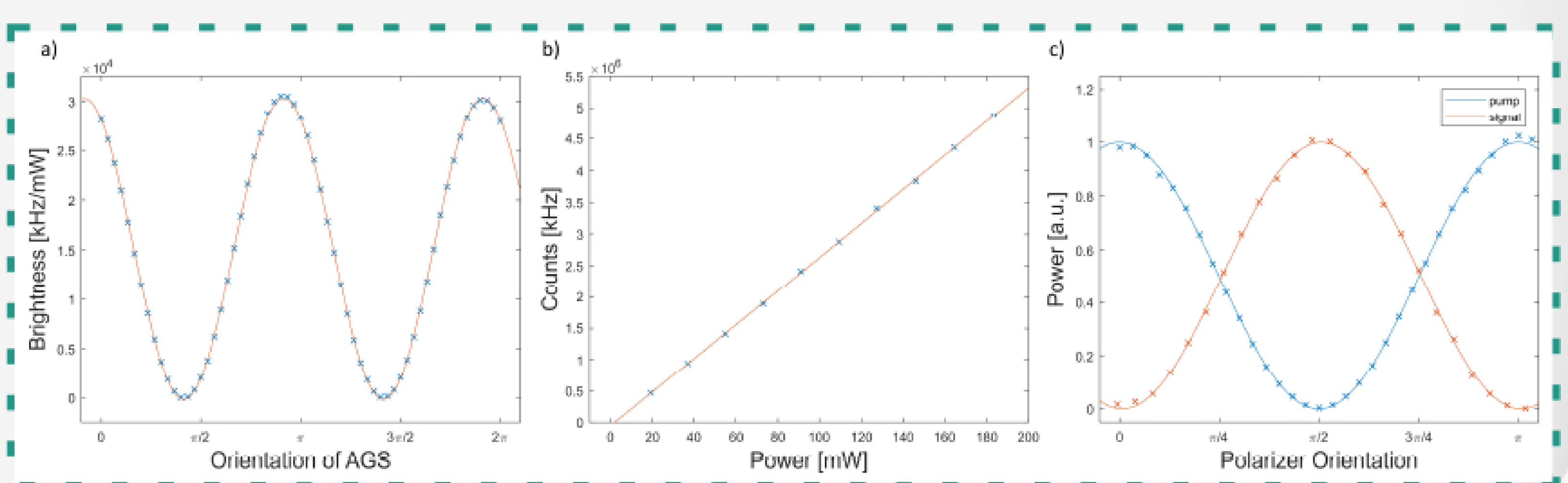

Fig. 4: a) Measured brightness of the AGS crystal as the SPDC source for different orientations of the AGS crystal with respect to the pump's linear polarization. b) Measured signal photon counts for different pump's optical powers. c) Measured normalized optical power of the pump and the signal for different orientations of the prism polarizer (blue markers and solid line represent the pump and orange markers and solid line represent the signal.

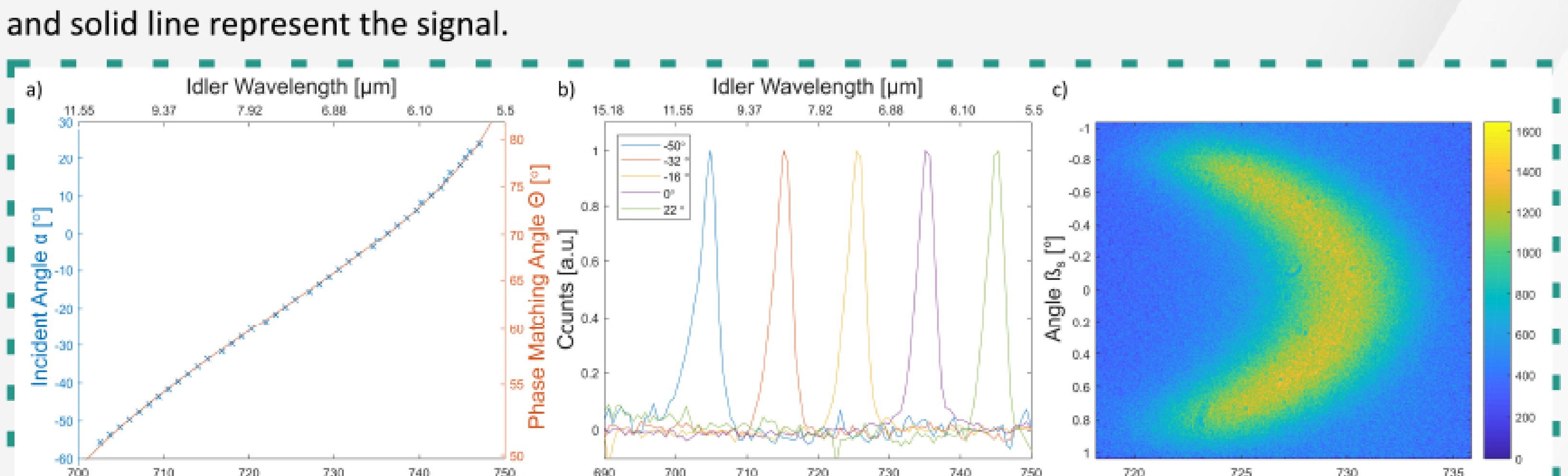

Fig. 5: a) Measured signal's central wavelength (blue markers) for angles α of the AGS crystal, realizing different polar angles Θ and calculated perfect phase matching polar angle (orange solid line). b) Measured spectrum of the signal for different rotation angles α of the AGS crystal and calculated corresponding idler wavelength as the upper x-axis. c) Measured frequency-angular spectrum of the signal photons.

References

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Experimental setup

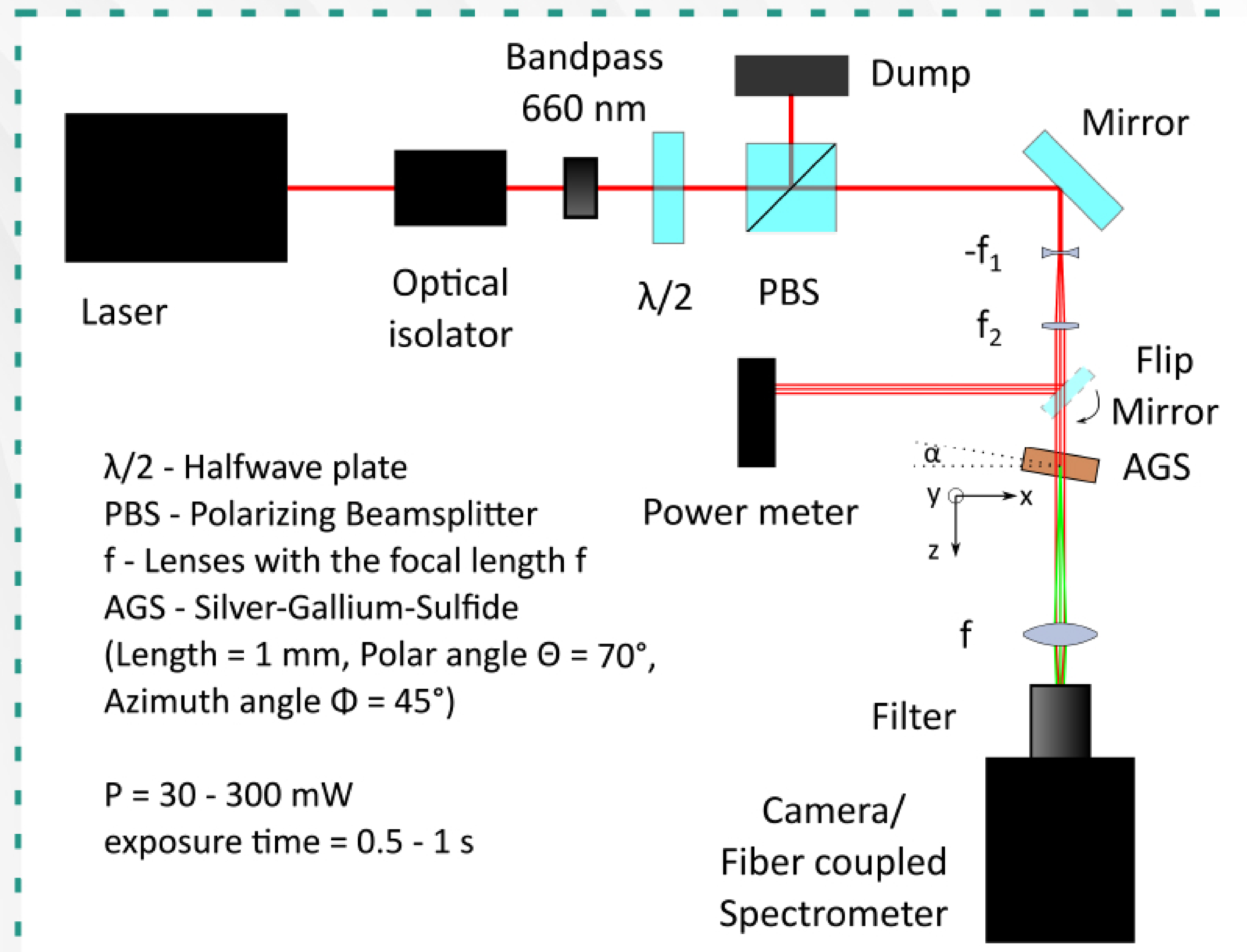

Fig. 3: Experimental setup for measuring the efficiency of the SPDC and properties of the generated signal photons. Red lines represent the pump beam and green lines represent the SPDC generated signal photons.

Experimental Results

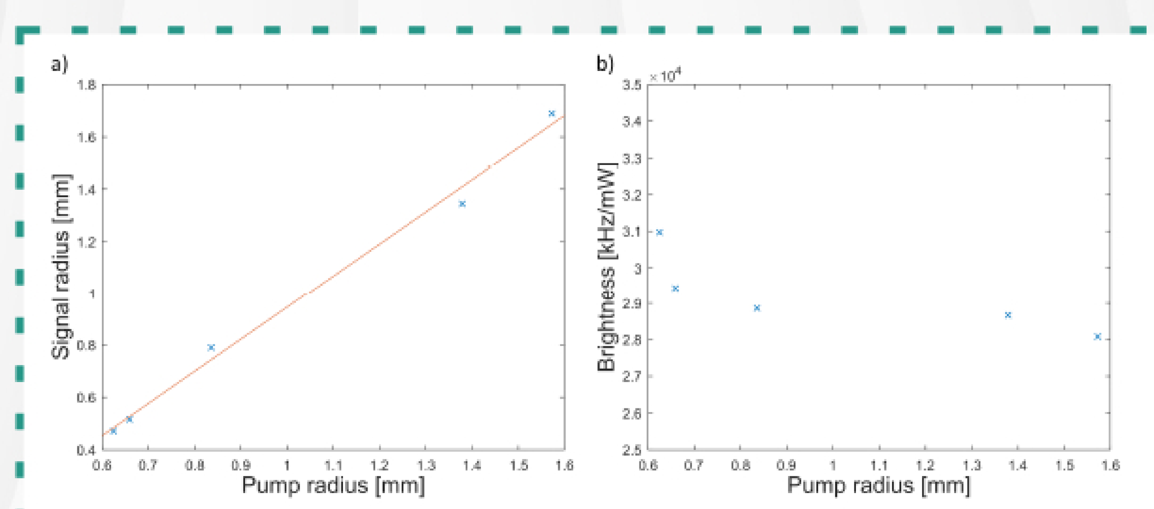

Fig. 6: a) Measured signal beam radius for different pump beam radii. b) Measured brightness of the photon source with increasing pump radius.

Future work

- Quantum imaging with undetected photons (QIUP) in the fingerprint region (5.6 µm up to 10.9 µm)
- Induced coherence without induced emission
- Resolution limit of the QIUP in momentum correlation configuration

$$\Delta = \frac{f_3 f_1}{f_2}\frac{\lambda_i}{\sqrt{2}\pi w_p}$$

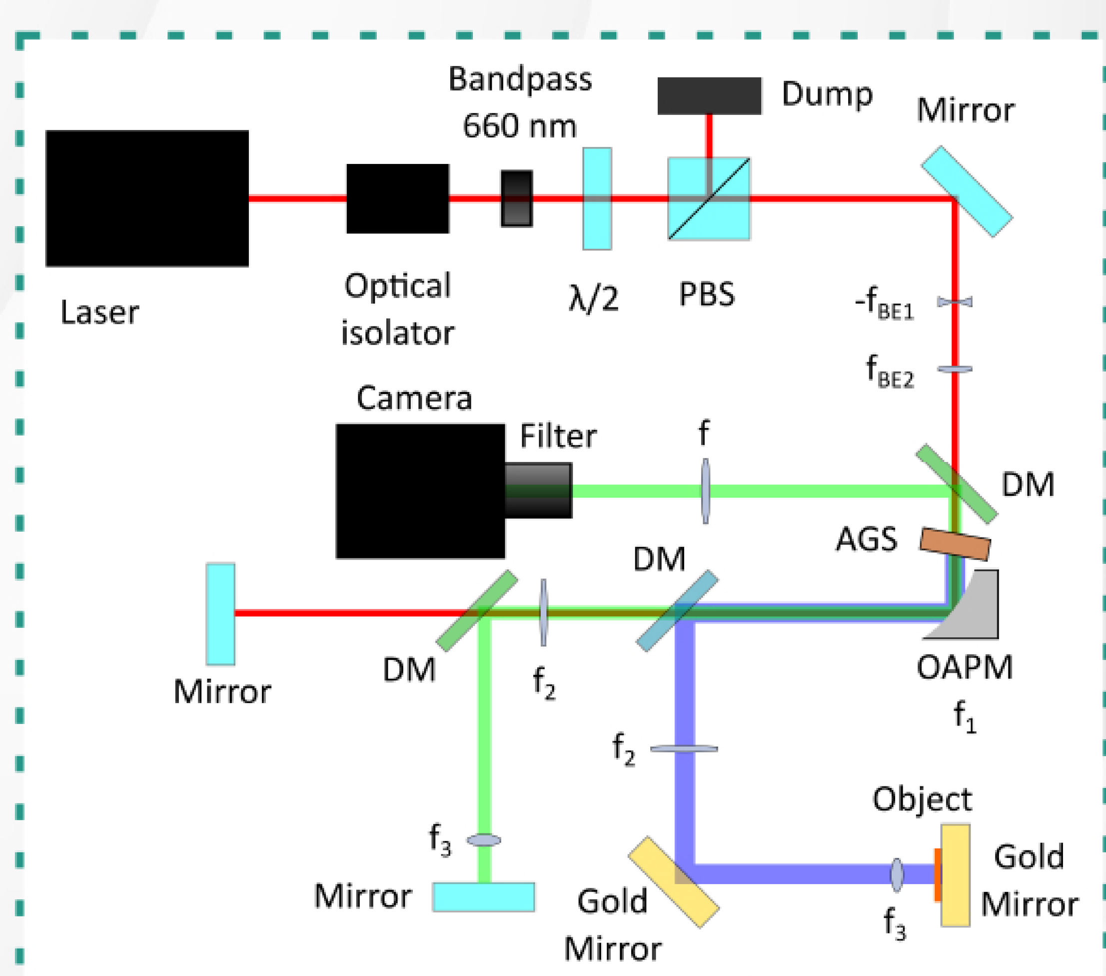

Fig. 7: Experimental setup for the Quantum Imaging with Undetected Photons (QIUP) in the configuration exploiting momentum correlation of the entangled signal-idler photon pair. Red lines represent the pump beam, green lines represent the SPDC generated signal photons and blue lines represent the SPDC generated idler photons. (λ/2 - halfwave plate, PBS - polarizing beamsplitter, AGS - silver-gallium-sulfide, DM - dichroic mirror, OAPM - off-axis parabolic mirror)

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