A source of polarization-entangled photons at 780 nm and 1550 nm wavelength

Adrian Holzäpfel

Motivation

Photonic qubit

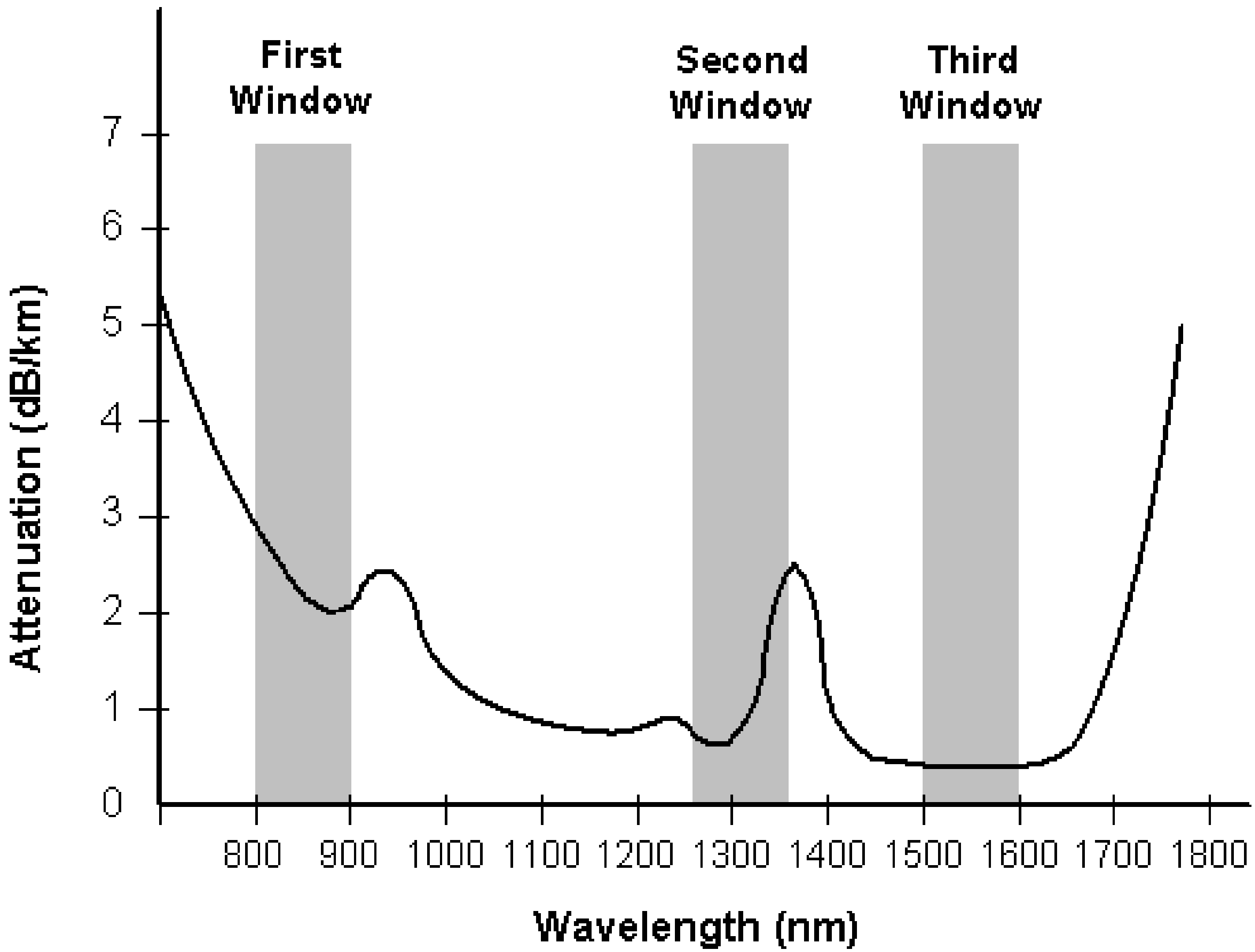
- Fast transmission
- Low error rate (per distance)
- High detection efficiency

- Universal (deterministic) gates
- Storage time

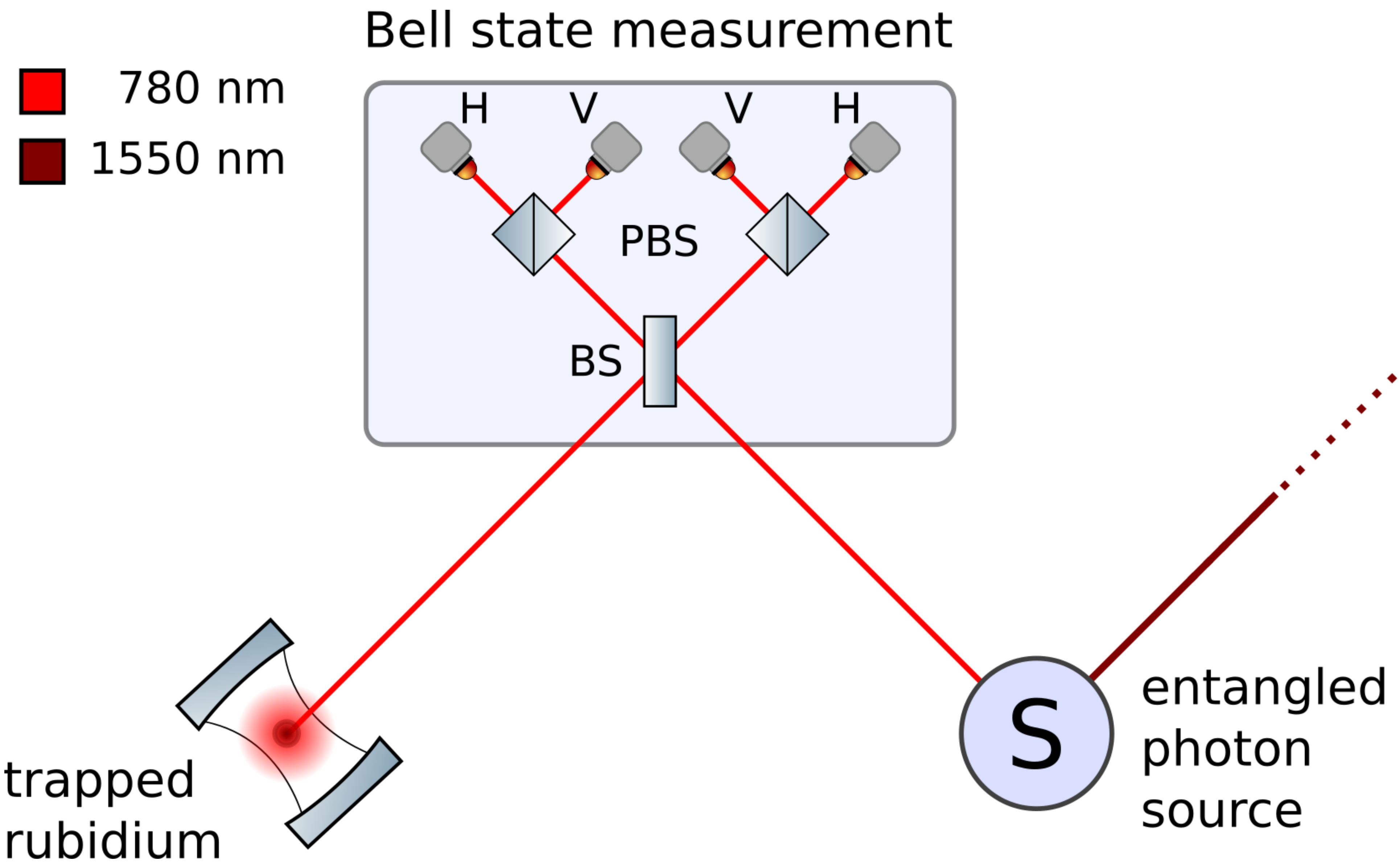
Trapped rubidium 87

- High state detection efficiency
- Universal deterministic gates
- Quantum registers
- Entanglement with 780 nm photons

Propagation loss in silica optical fibers

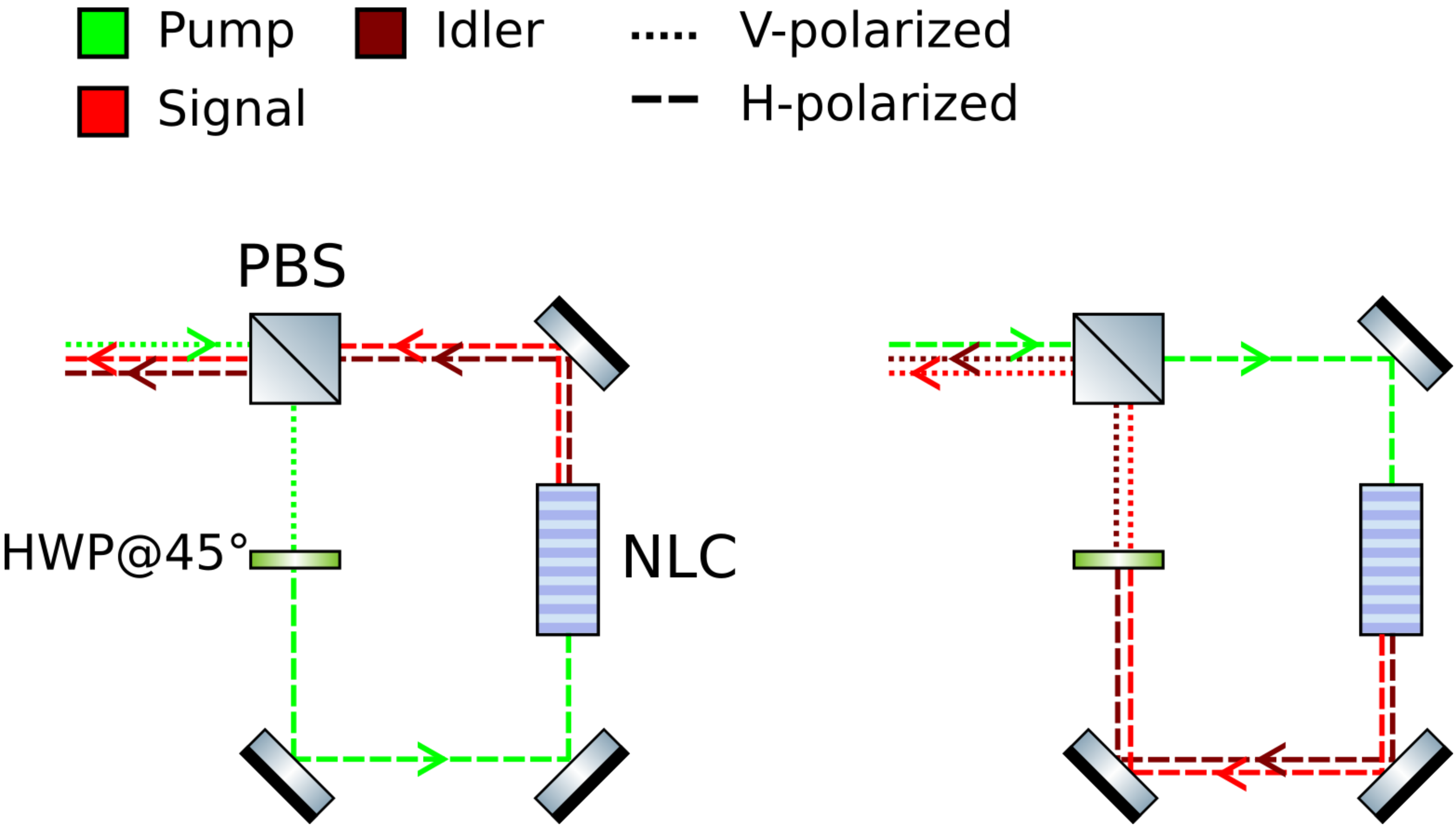


Taken from http://www.macao.communications.museum

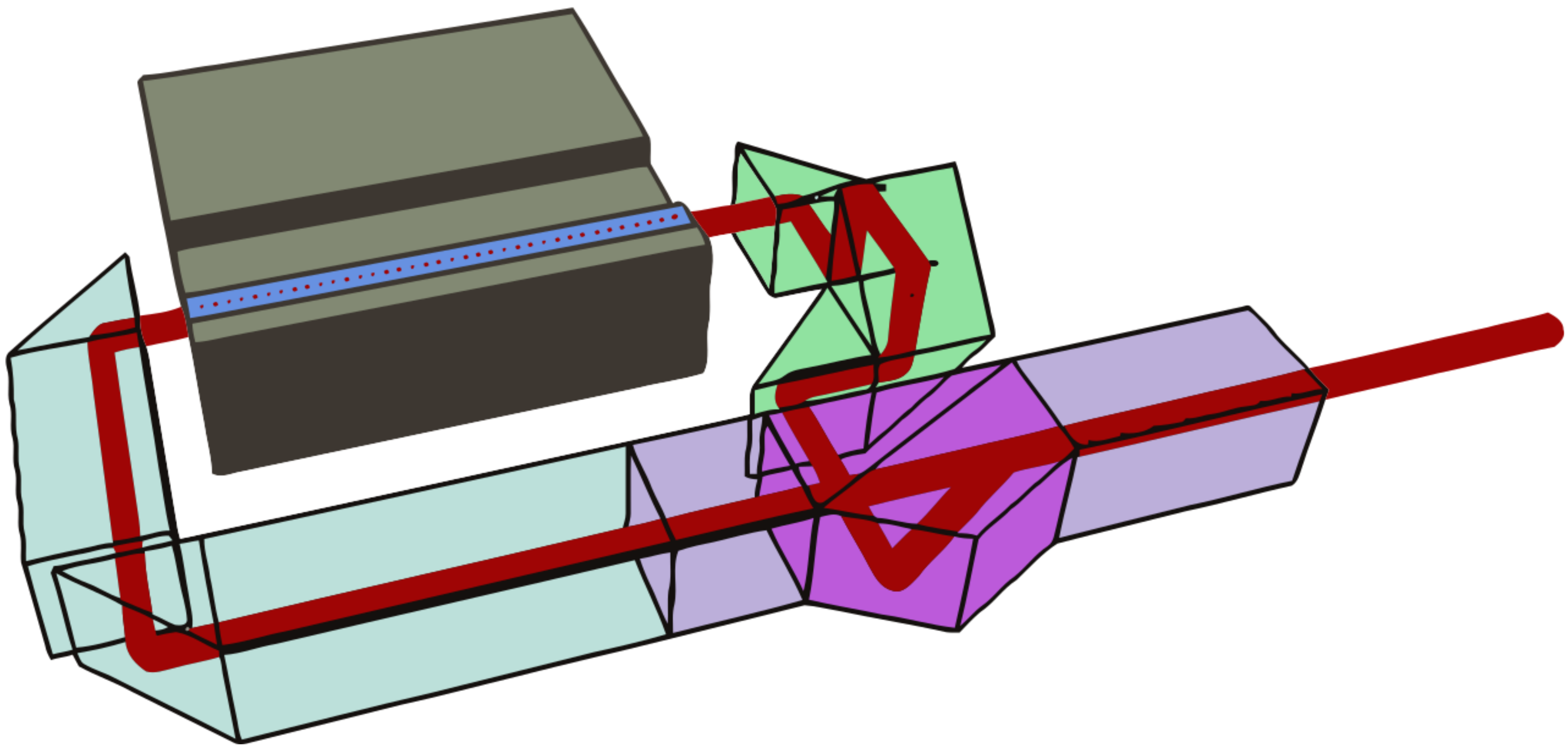

Bell state measurement
780 nm
1550 nm
H
V
V
H
PBS
BS
trapped
rubidium
S
entangled
photon
source

Experimental Setup

Entanglement creation in Sagnac-interferometer



■	Nonlinear Crystal	■	Glan-Thompson prism
■	Glass	■	Calcite block
		■	Polarization rotator



- Nonlinear Crystal
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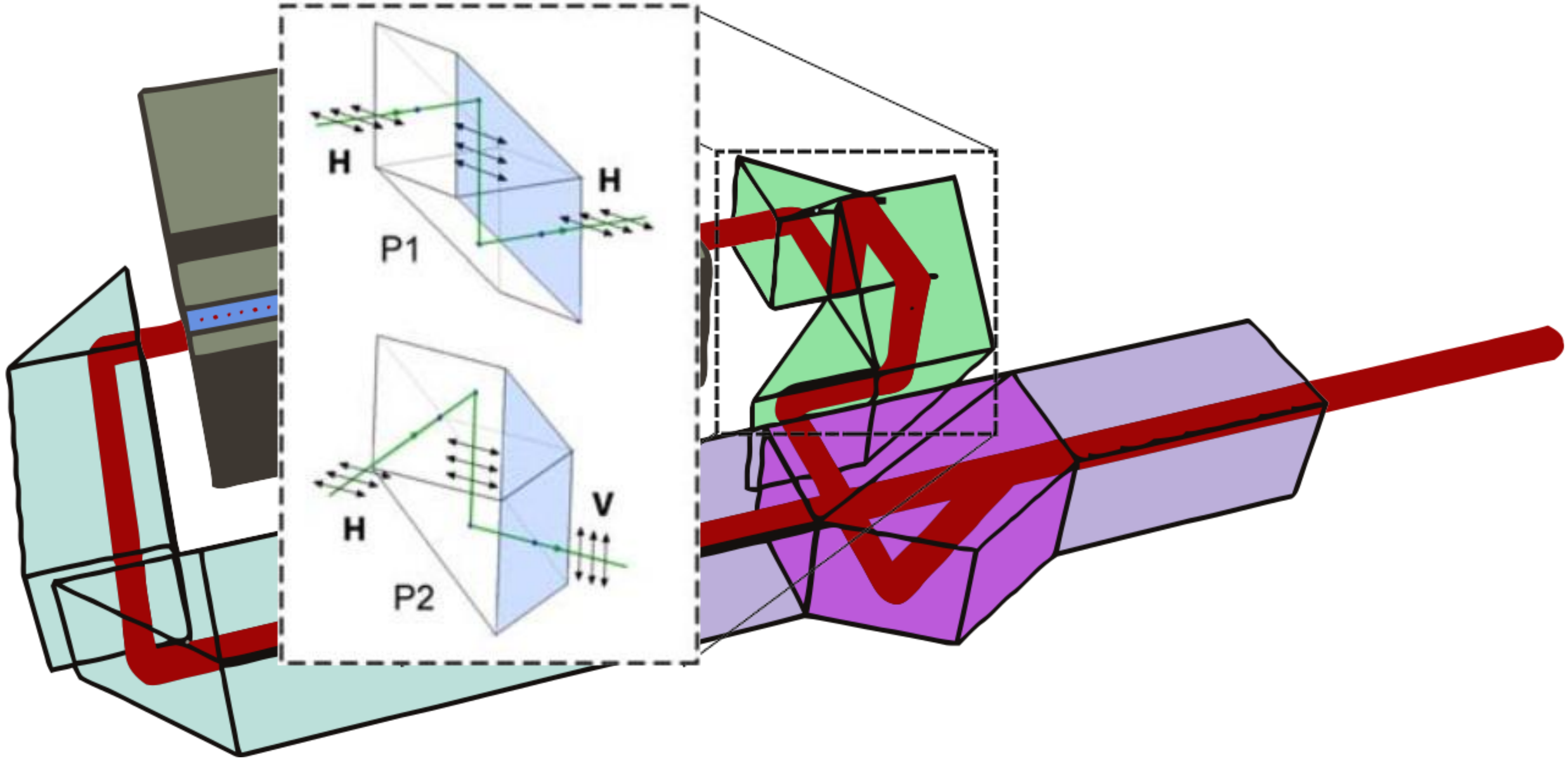
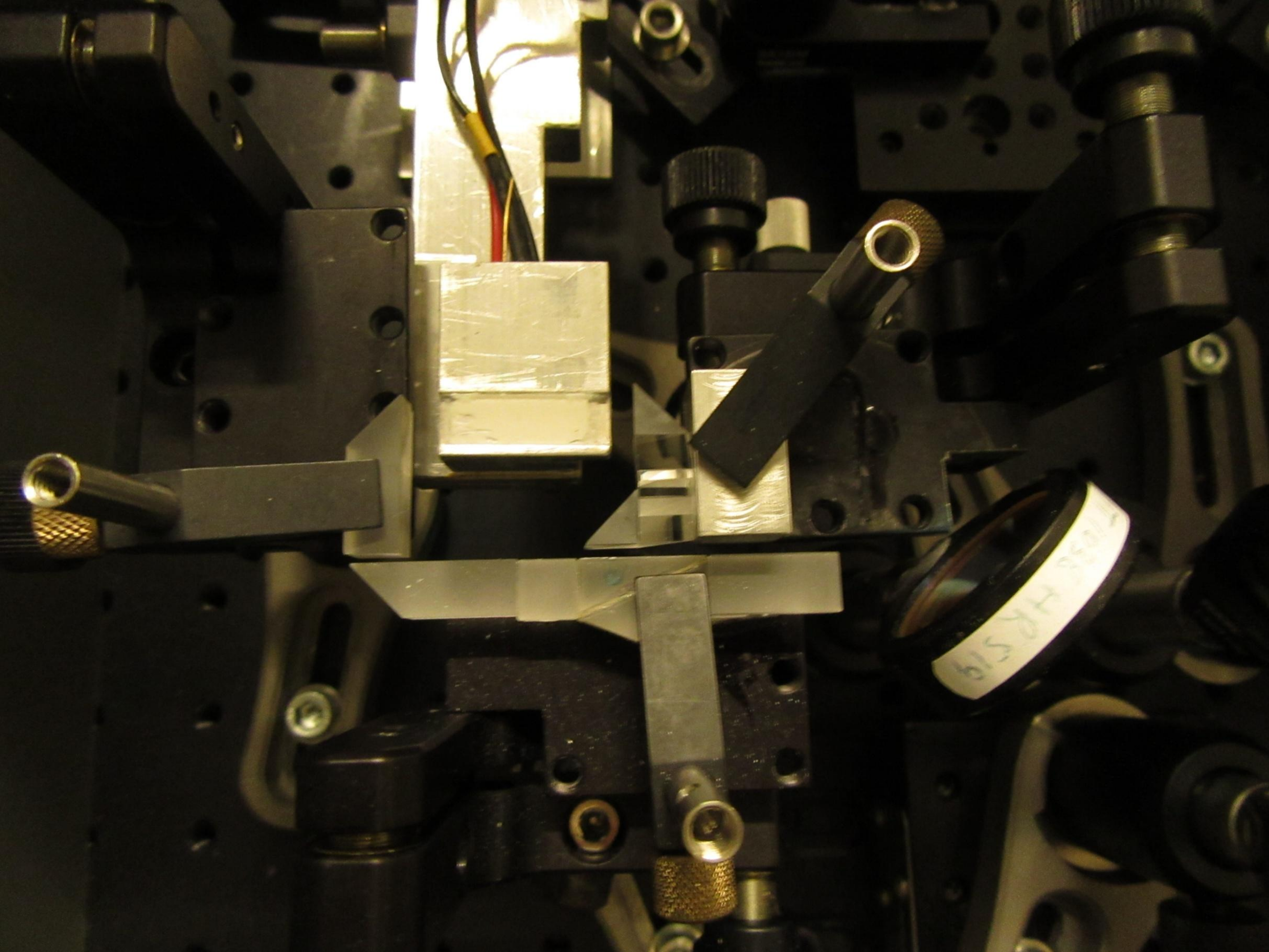
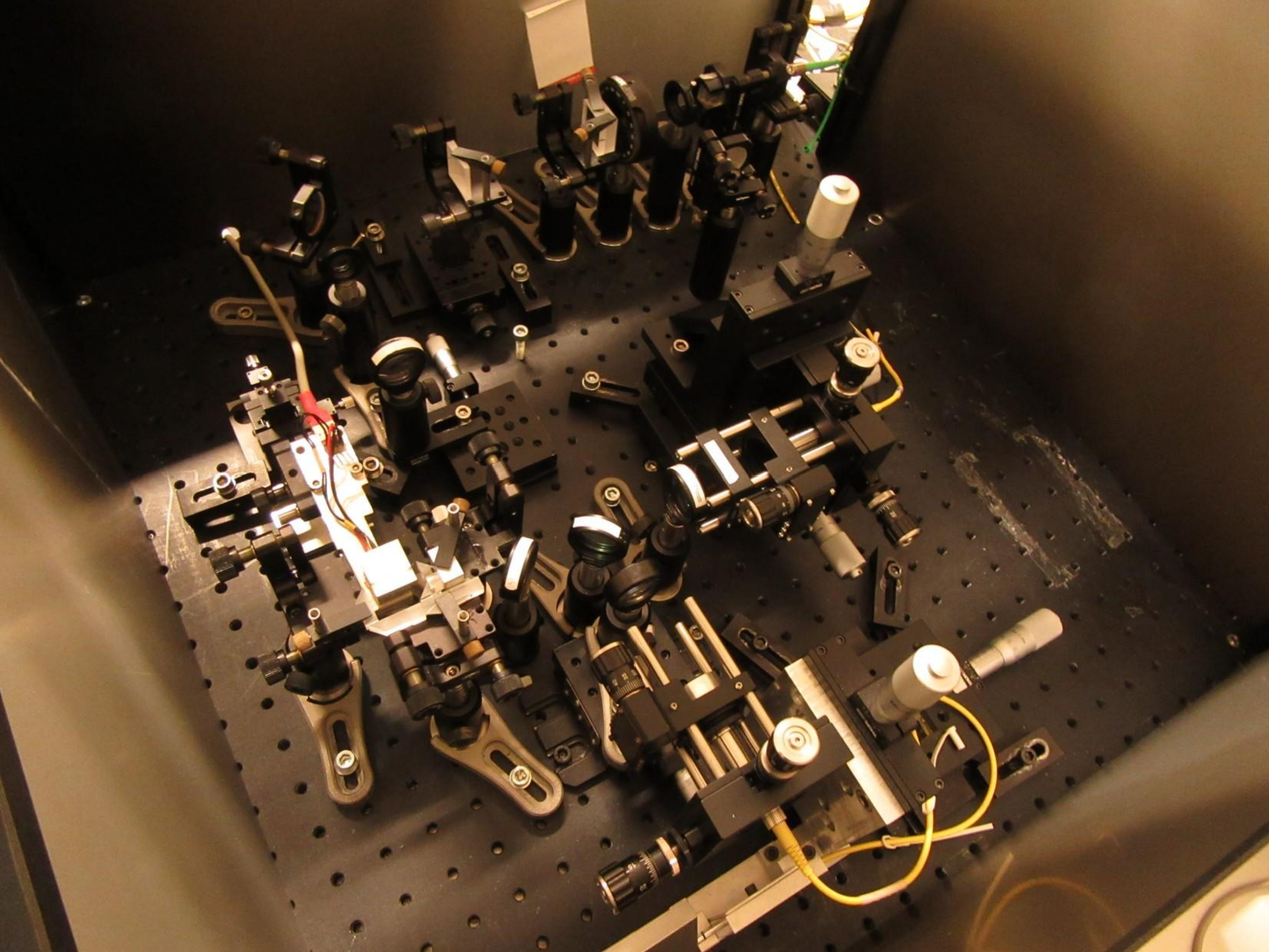
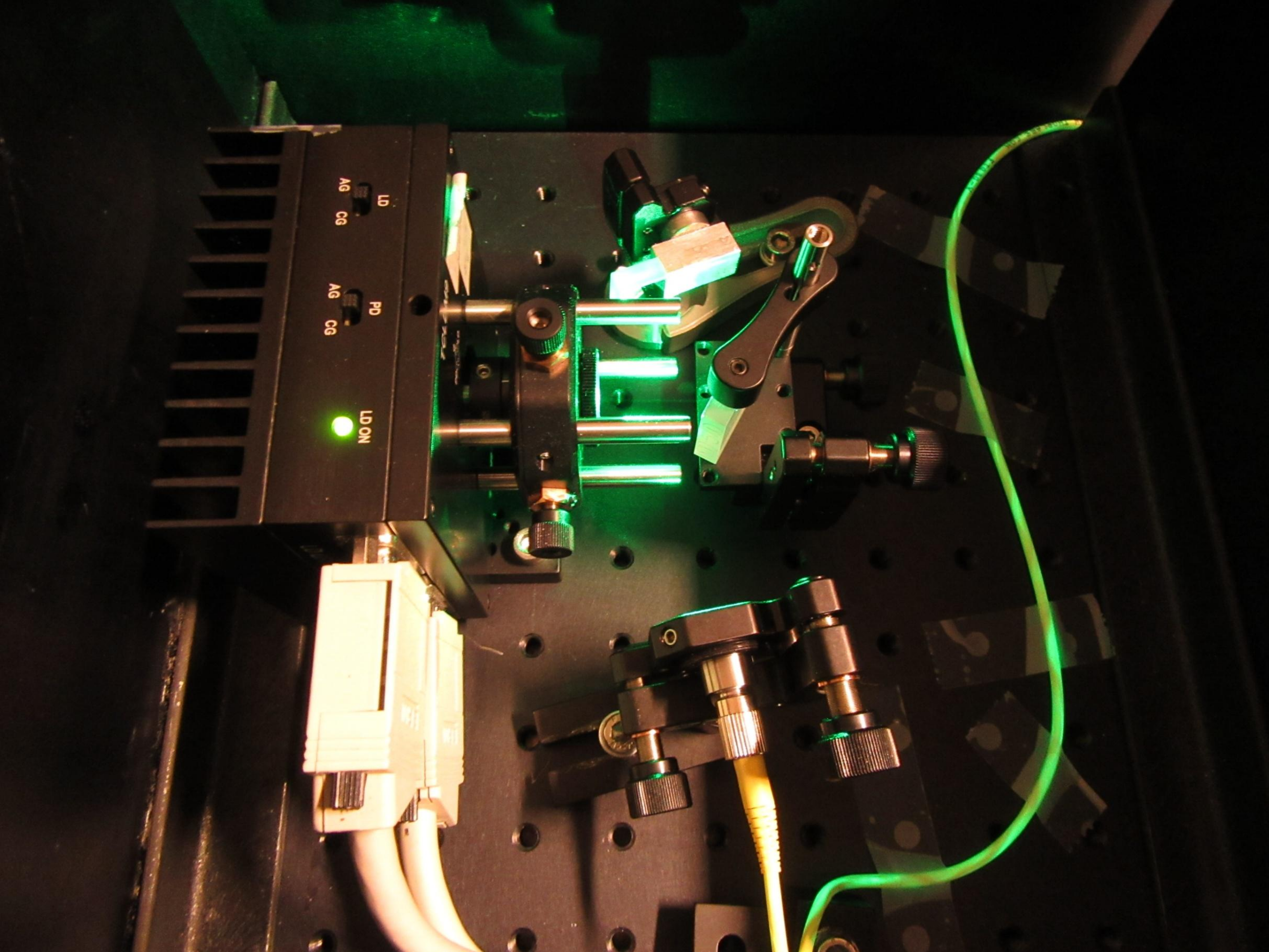







LD
AG
CG
PD
AG
CG
LD ON

Performance

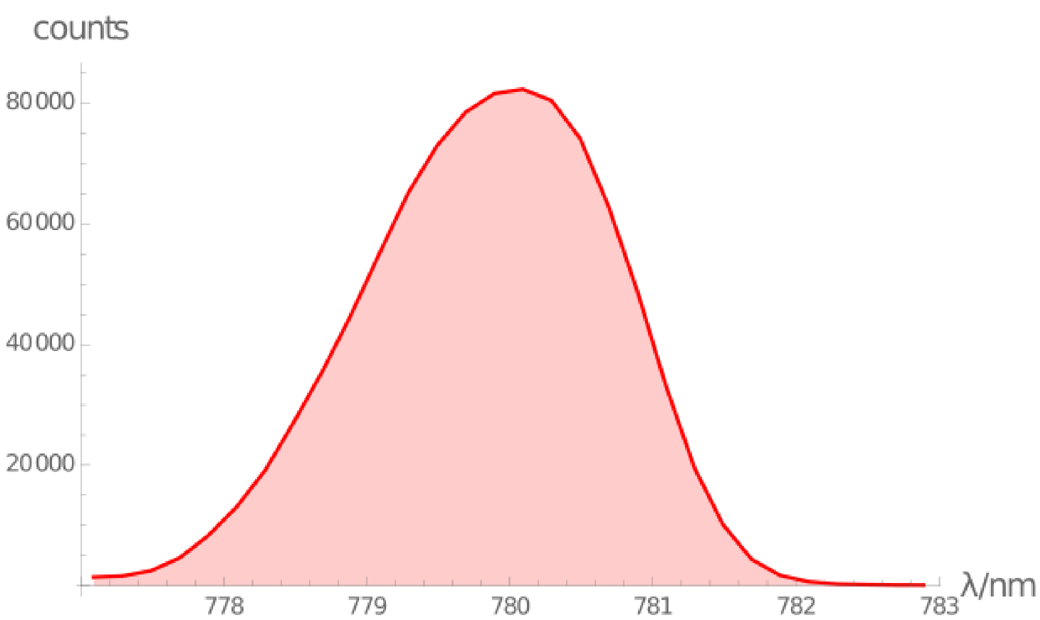
Performance

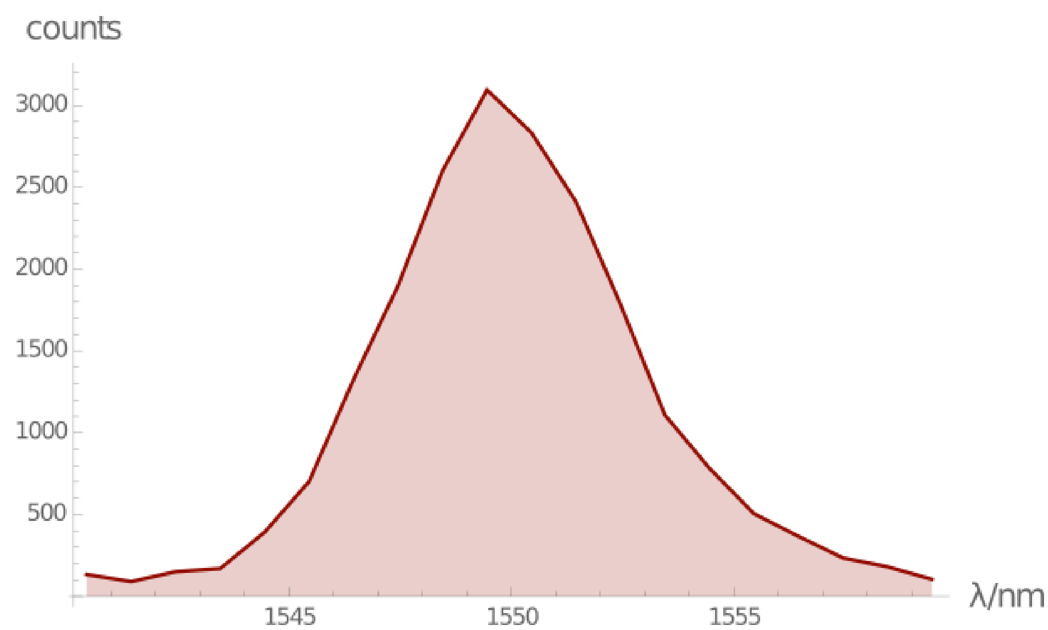
- **Spectral:** Central wavelength and spectral width of signal and idler

- **Rates:** Collection efficiency and (spectral) brightness

- **State preparation:** Correlation measurements and quantum state tomography

Single photon spectra





$$\Delta\lambda_S = 2.0 \pm 0.1\text{nm}$$

$$\Delta\lambda_I = 6.0 \pm 0.5 \text{ nm}$$

Estimating collection efficiency

- Signal and idler are created strictly in pairs

⇨ $$\frac{R_{AB}}{R_B} = \frac{\eta_A \eta_B R_{tot}}{\eta_B R_{tot}} = \eta_A$$

$$\eta_S^{(c)} = 12.8\%$$

$$\eta_I^{(c)} = 10.0\%$$

Contributions to photon loss

• Interferometer:	
vertically polarized:	33%
horizontally polarized:	59%
• Bandpass filters:	
780 nm:	20%
1550 nm:	50%
• Coupling into SM fibers:	35%

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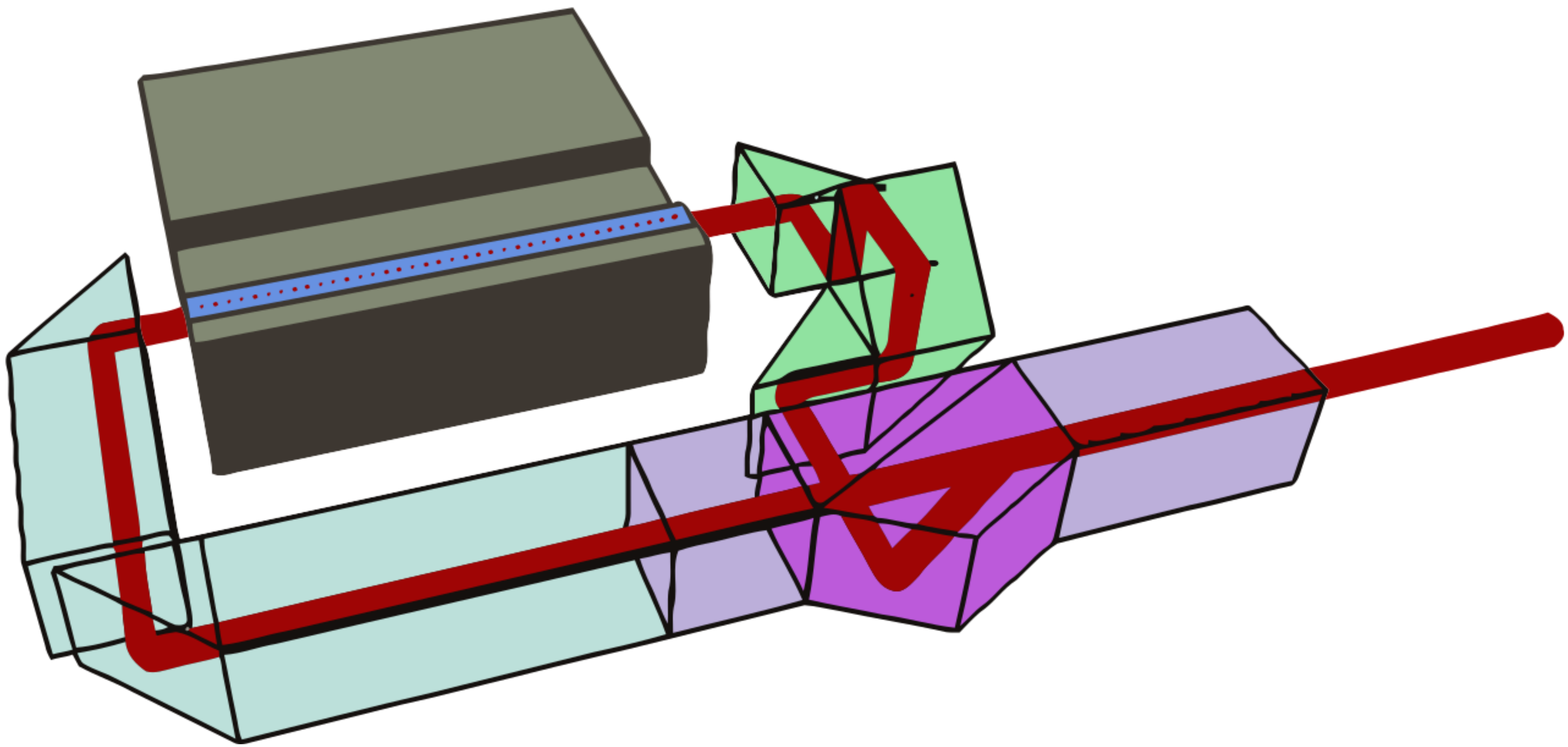

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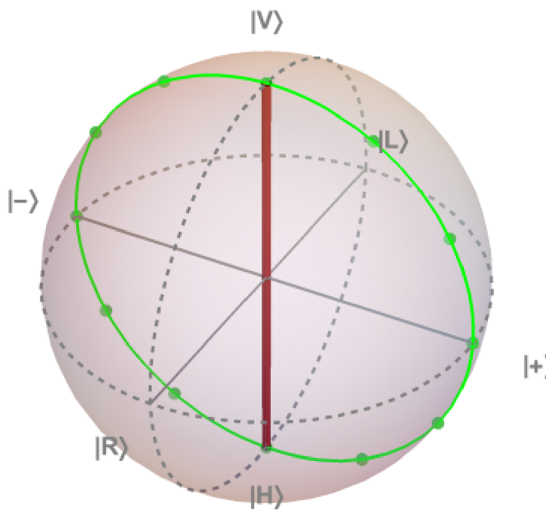
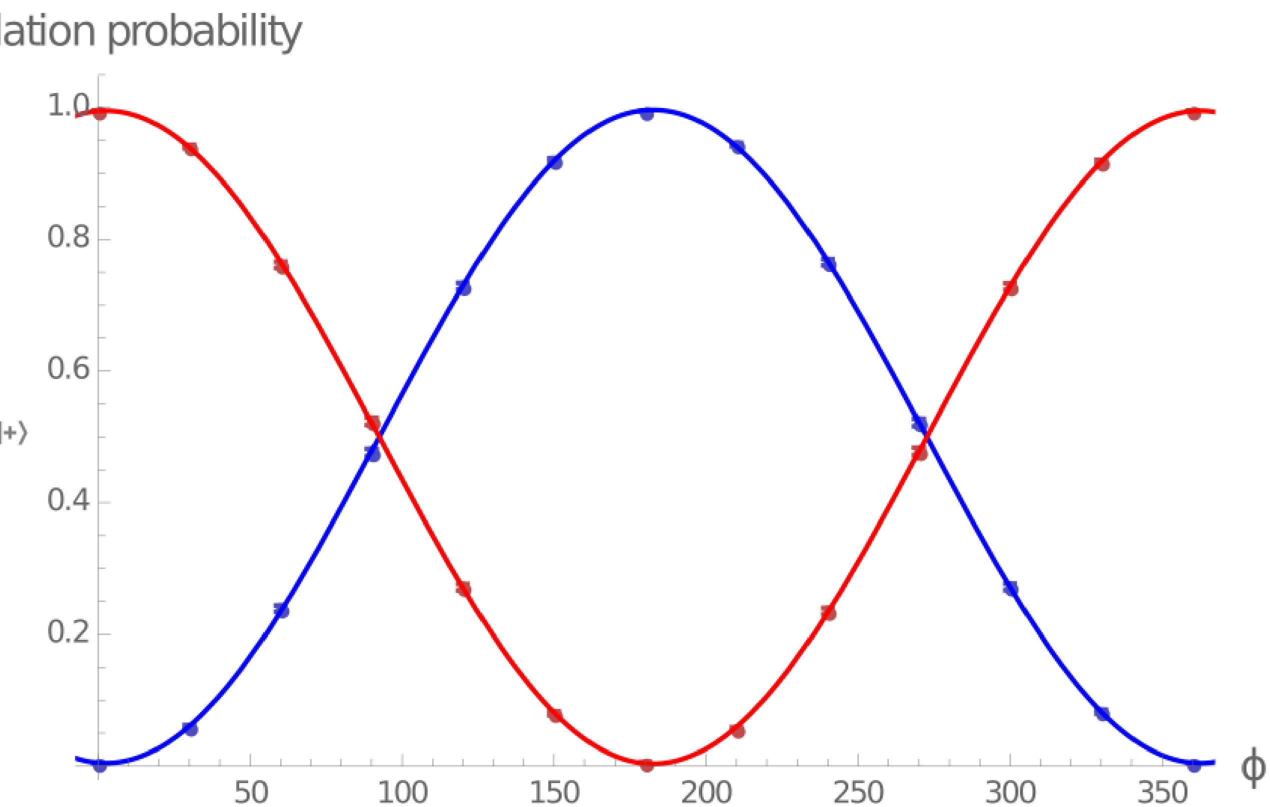
Brightness and spectral brightness

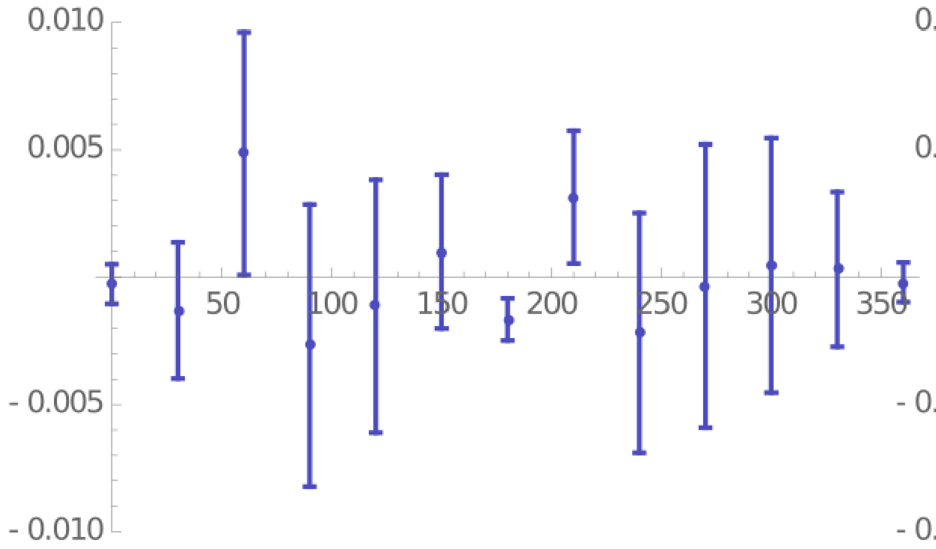
$$B := \frac{R_{SI}^{(\mathrm{created})}}{P_{\mathrm{pump}}} = \frac{R_{SI}^{(\mathrm{measured})}}{P_{\mathrm{pump}}\eta_S\eta_I} = 2.4 \times 10^6 \mathrm{s}^{-1}\mathrm{mW}^{-1}$$

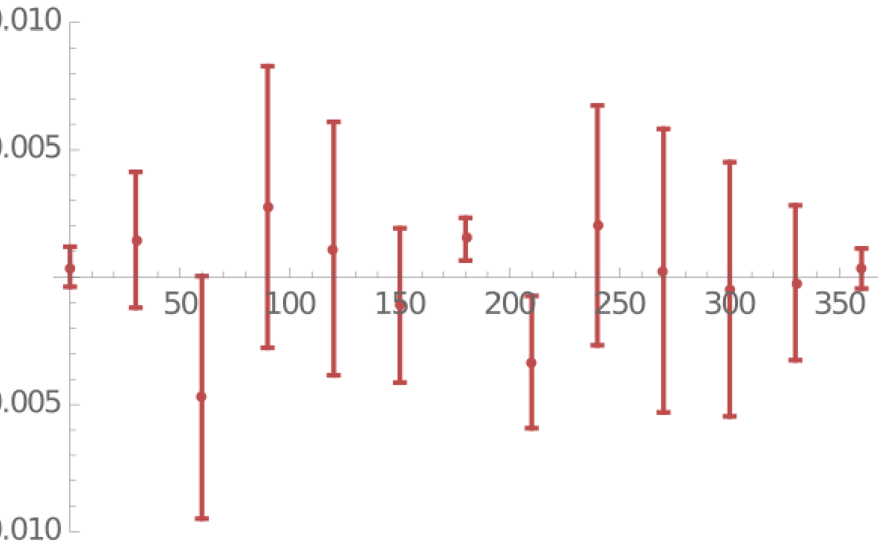
$$B_{\mathrm{spect}} := \frac{B}{\Delta\nu_S} = 2.6 \times 10^6 \mathrm{s}^{-1}\mathrm{mW}^{-1}\mathrm{THz}^{-1}$$

Performance

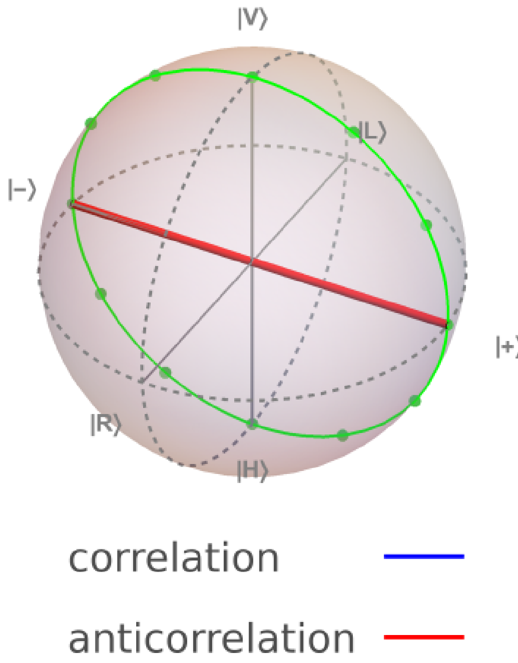


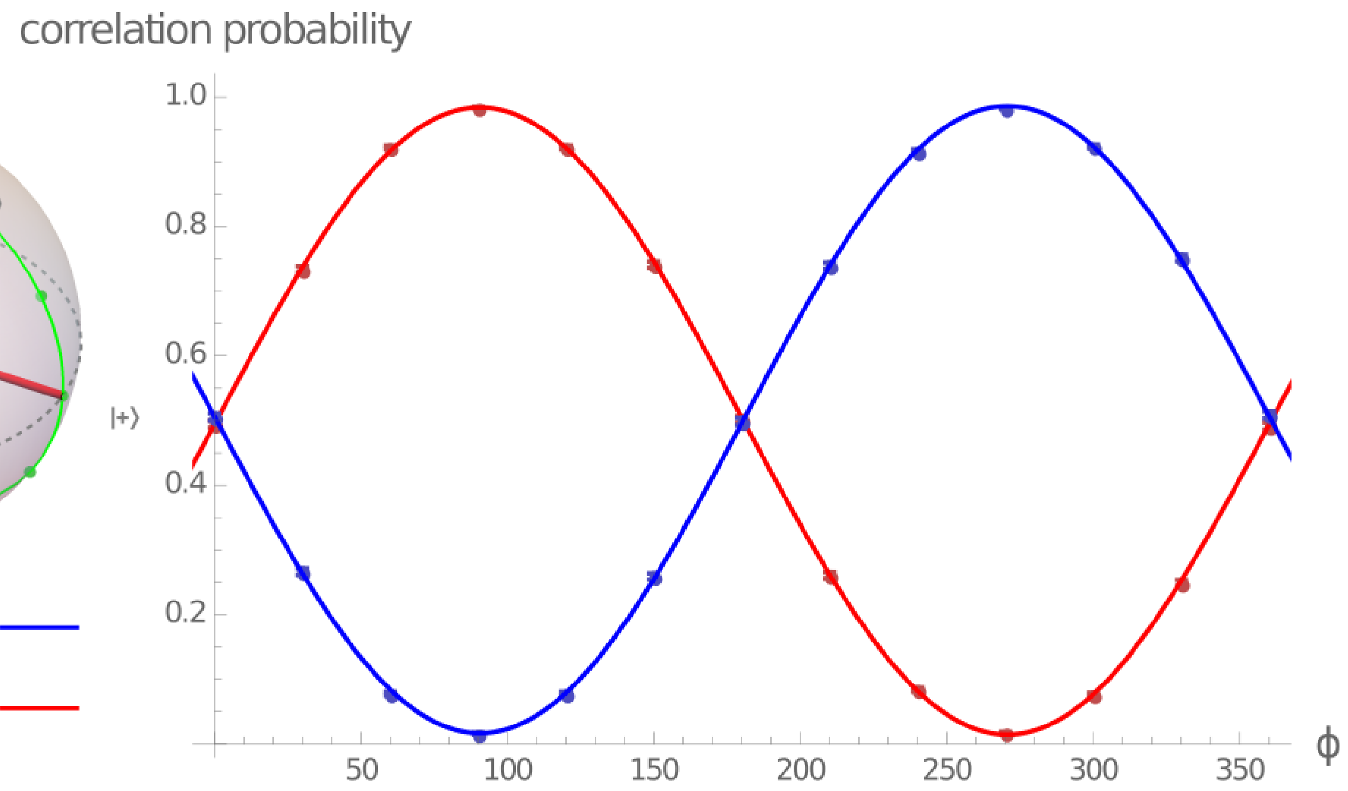


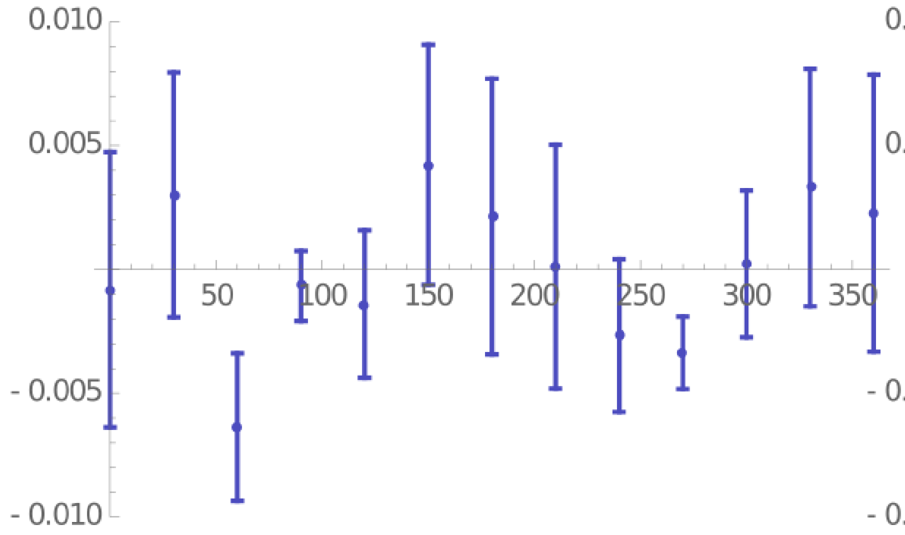


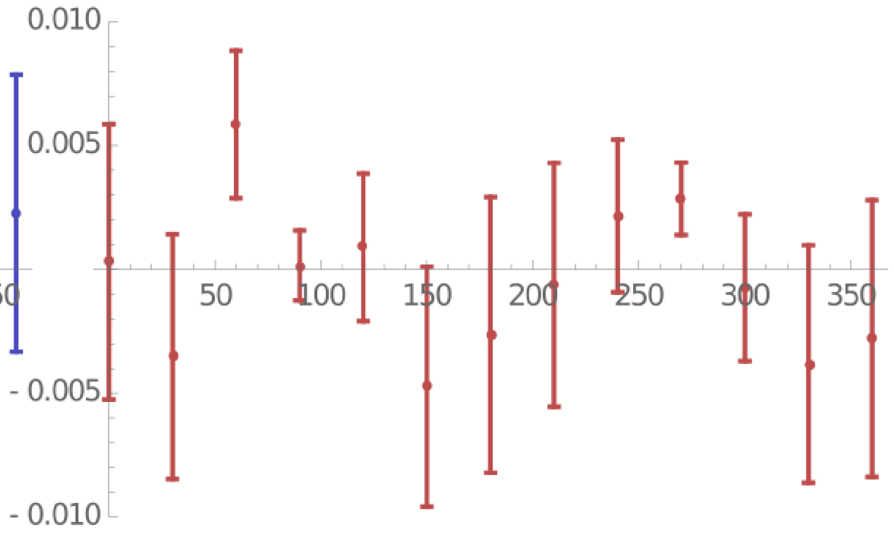


Performance









State tomography with maximum likelihood method

1)Find suitable parametrization for $\bar{n}\hat{\rho}$

⇨ Cholesky decomposition: $\bar{n}\hat{\rho} = \hat{T}\hat{T}^{\dagger}$

2)Formulate a likelihood as function of the parametrisation

3)Numerically maximize the likelihood for the given measurement result

$$\mathcal{L}(t_1, \ldots, t_{16}) = \frac{1}{N} \prod_i exp\left(-\frac{(\bar{n}_i - n_i)^2}{2\sigma_i^2} \right)$$

$$= \frac{1}{N} \prod_i exp\left(-\frac{(\langle i| \hat{T}^\dagger \hat{T} |i\rangle - n_i)^2}{2 \langle i| \hat{T}^\dagger \hat{T} |i\rangle} \right)$$

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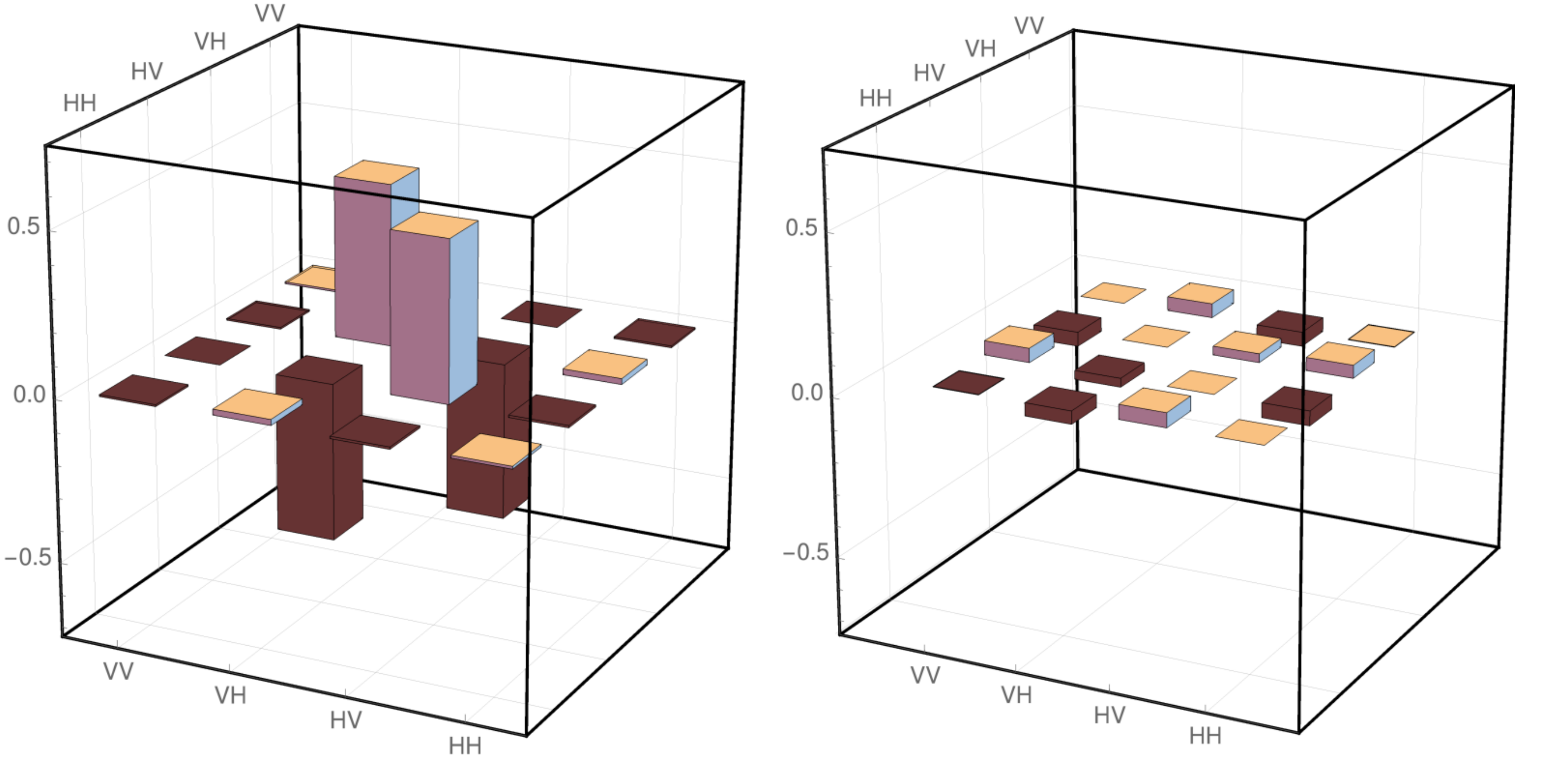
Reconstructed density matrix



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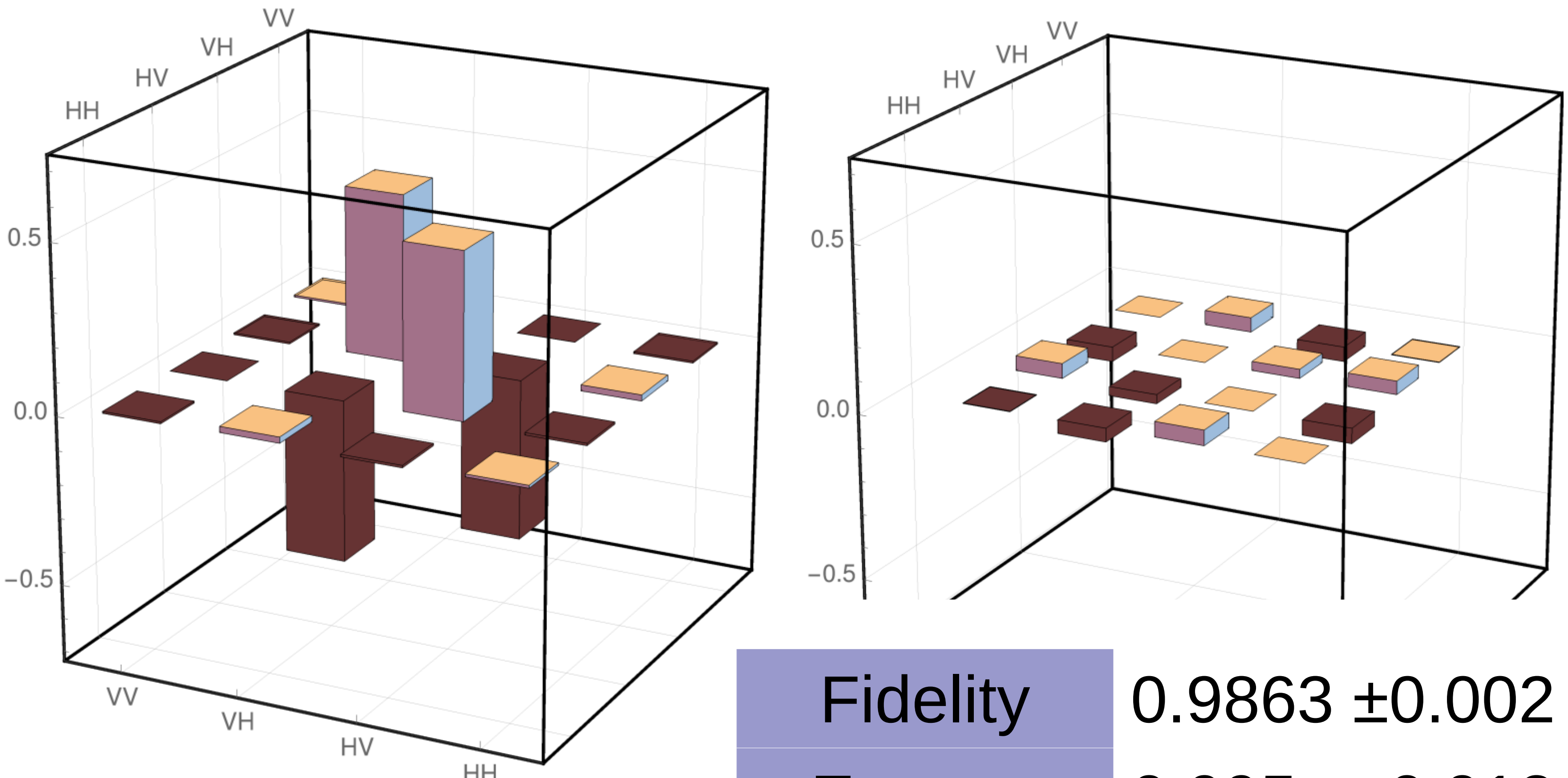

Fidelity	0.9863 ±0.002
Entropy	0.095 ±0.012
Negativity	0.964 ±0.005

Conclusion

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- High fidelity
- Compact
- Stable

- Coupling efficiency
- Spectrum of SPDC

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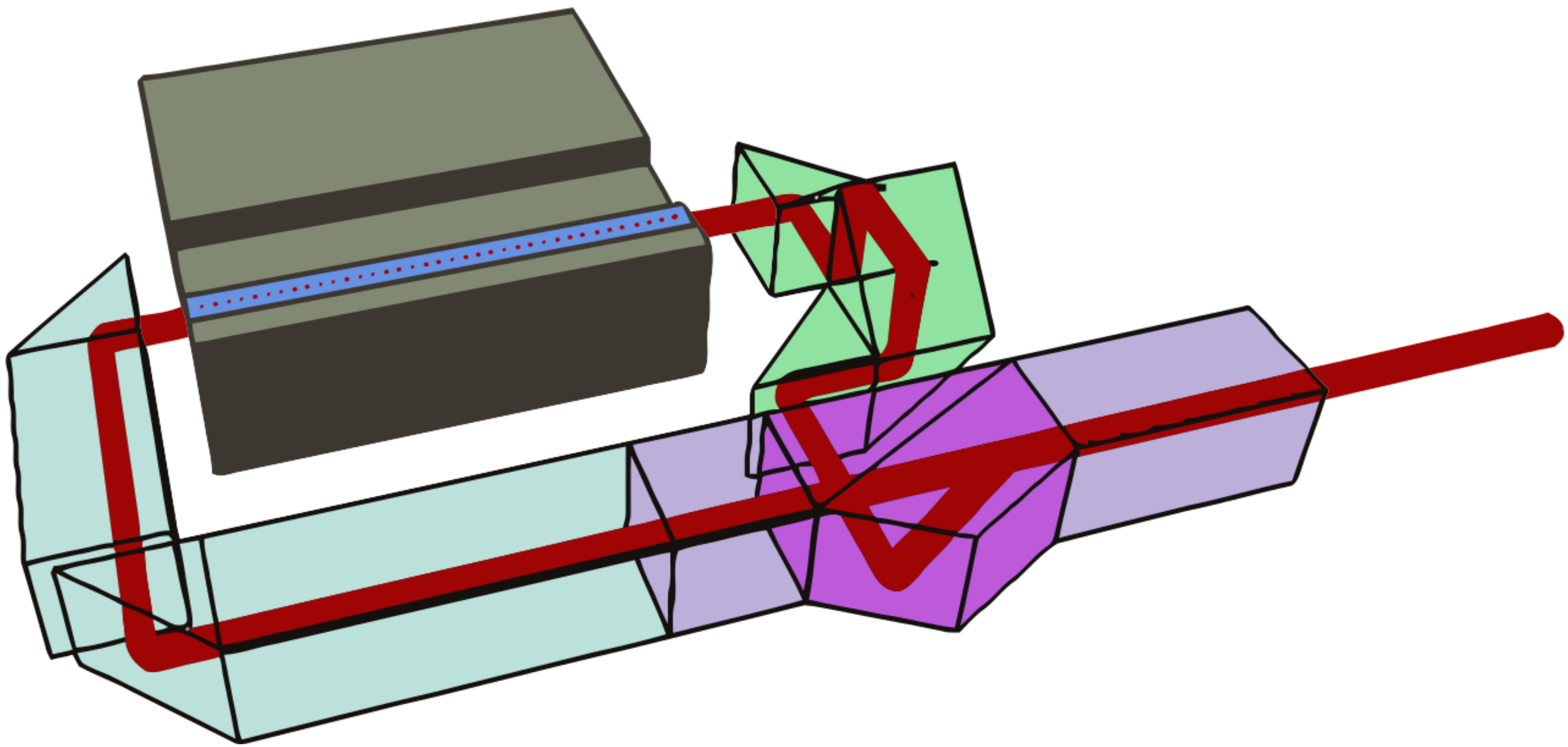

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