ARO-DARPA Quantum Communications & Quantum Memory Initiative Kick-Off Meeting

High-Flux Narrowband Polarization Entanglement Source

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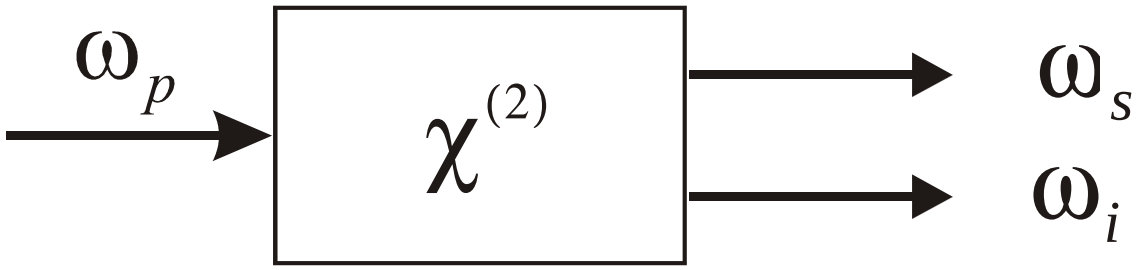
Polarization-Entangled Photon Source

Photon #1 Photon #2

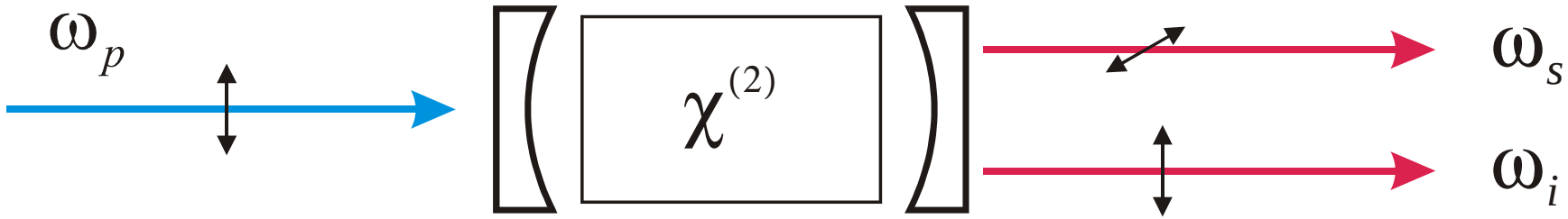
- Photon #1 is randomly polarized
- Photon #2 is also randomly polarized
- Photons #1 and #2 are always orthogonally polarized (or some other known fixed relative orientation)

Optical Parametric Downconversion



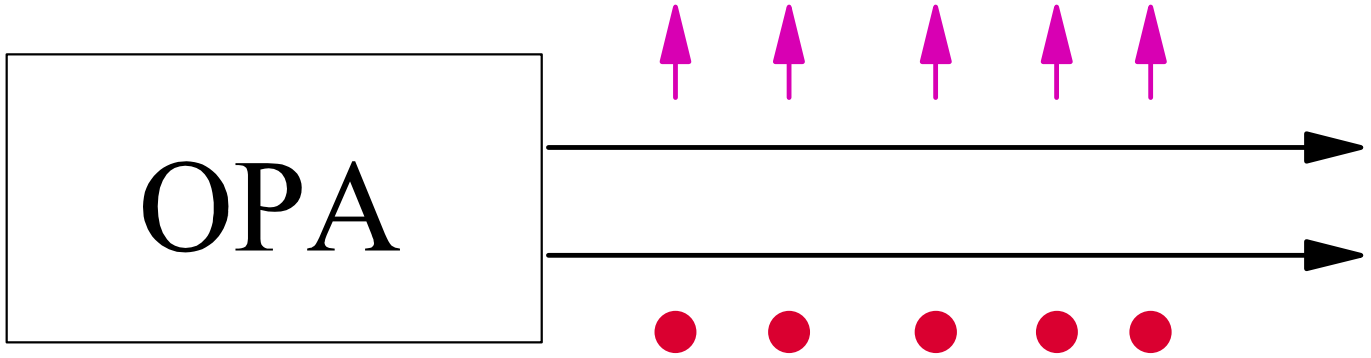
- Energy conservation: $\omega_s + \omega_i = \omega_p$
- ω_s and ω_i photons are generated simultaneously
- $\perp$ or $\parallel$ polarized, depending on phase matching
- Kwiat *et al*, Phys. Rev. **A 60**, R773 (1999)
  - $1.5 \times 10^6\ s^{-1}$, 5 nm BW @ 702 nm, 150 mW pump
  - spectral brightness: $15\ s^{-1}$ over a 30-MHz BW

Doubly Resonant OPA



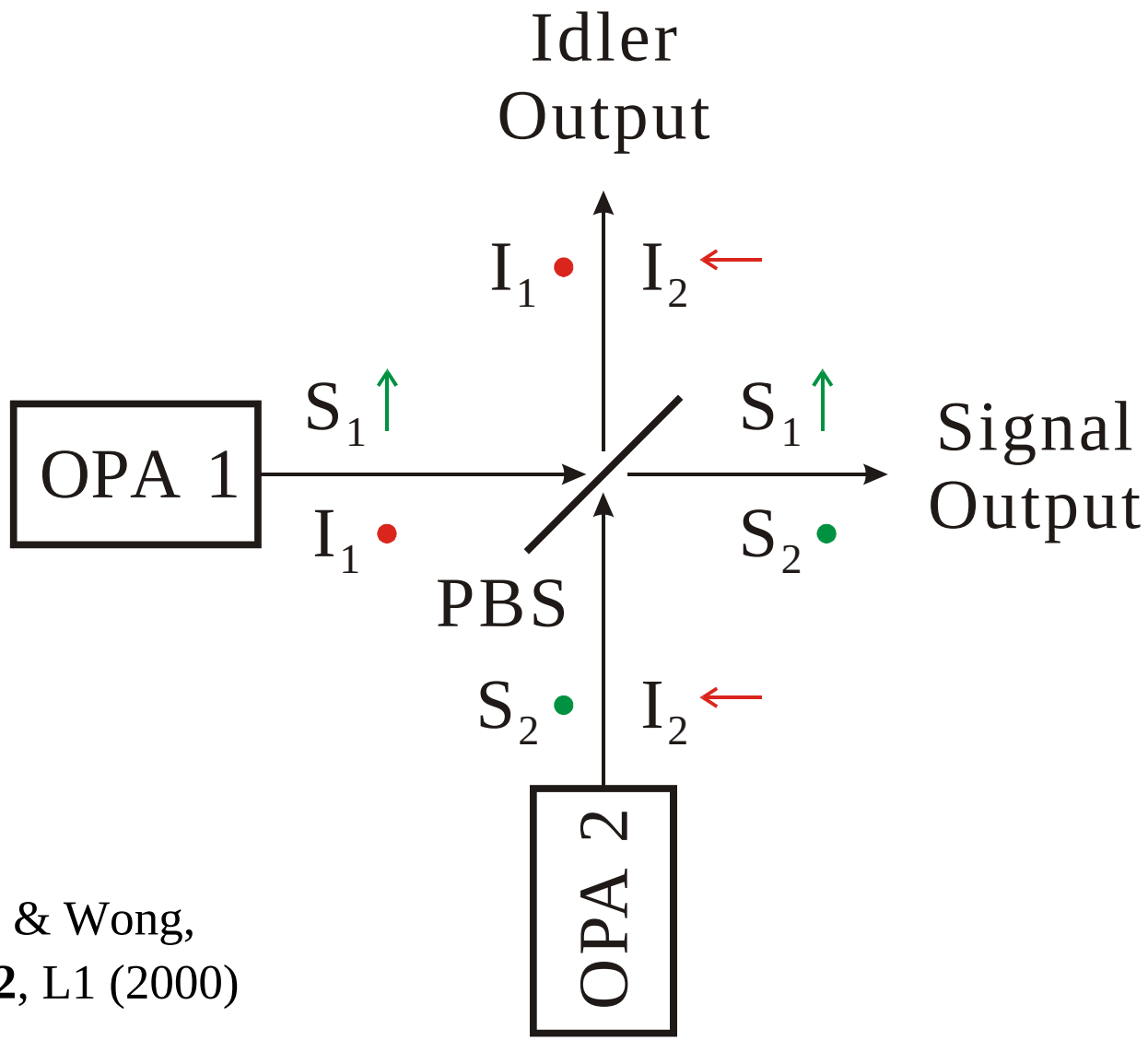
- Cavity is resonant at signal and idler fields
  - Significantly lower pump power
  - $1.5 \times 10^6\ s^{-1}$ in 30 MHz @ 1% of threshold pumping
  - Well defined spatial mode
  - Adjustable BW and generation rates
  - Selectable wavelengths via quasi-phase matched nonlinear materials

Polarization-entangled photon pairs



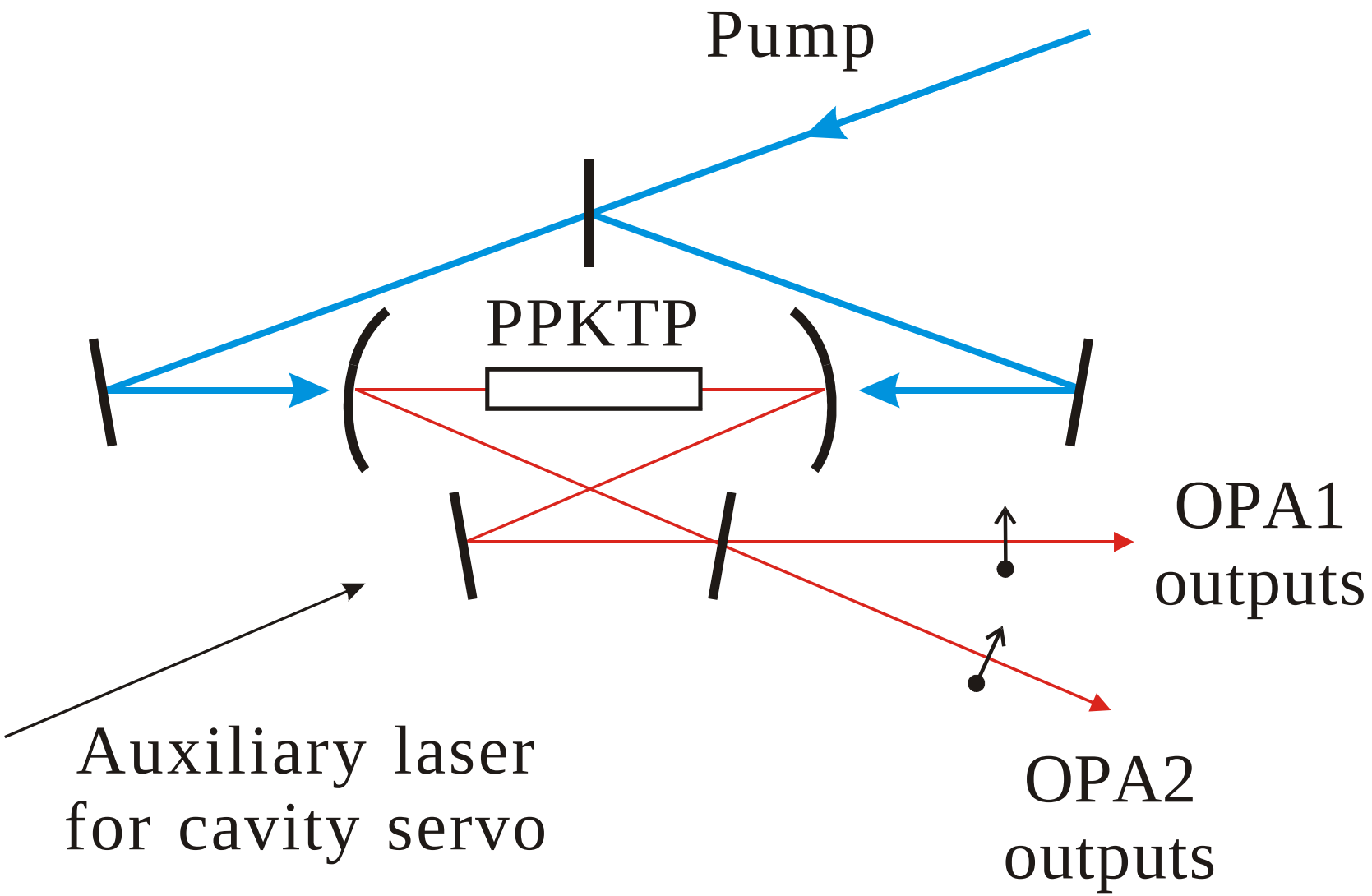
- Simultaneous generation of photon pairs: time correlated
- Orthogonal polarization: polarization correlated
- 2 OPAs => arbitrary-polarization entangled beams

Type-II Dual-OPA Entanglement Source

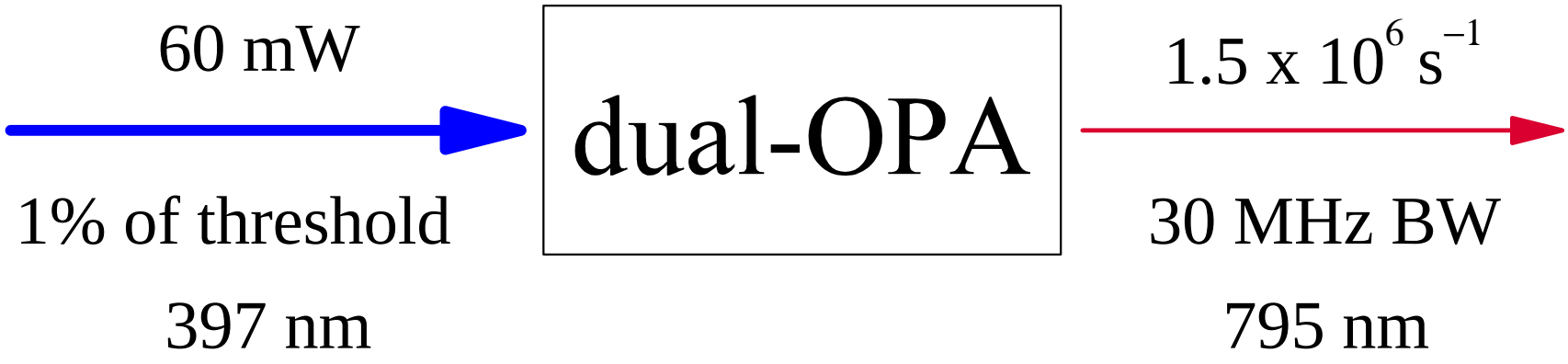


Shapiro & Wong,
J. Opt. B **2**, L1 (2000)

Dual-OPA Ring-Cavity Implementation

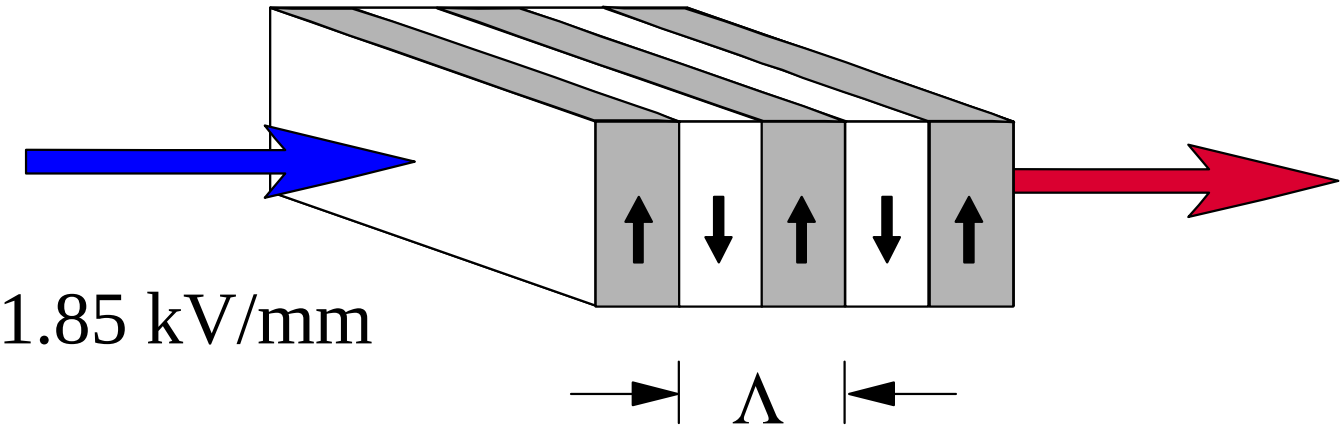


PPKTP Dual-OPA System



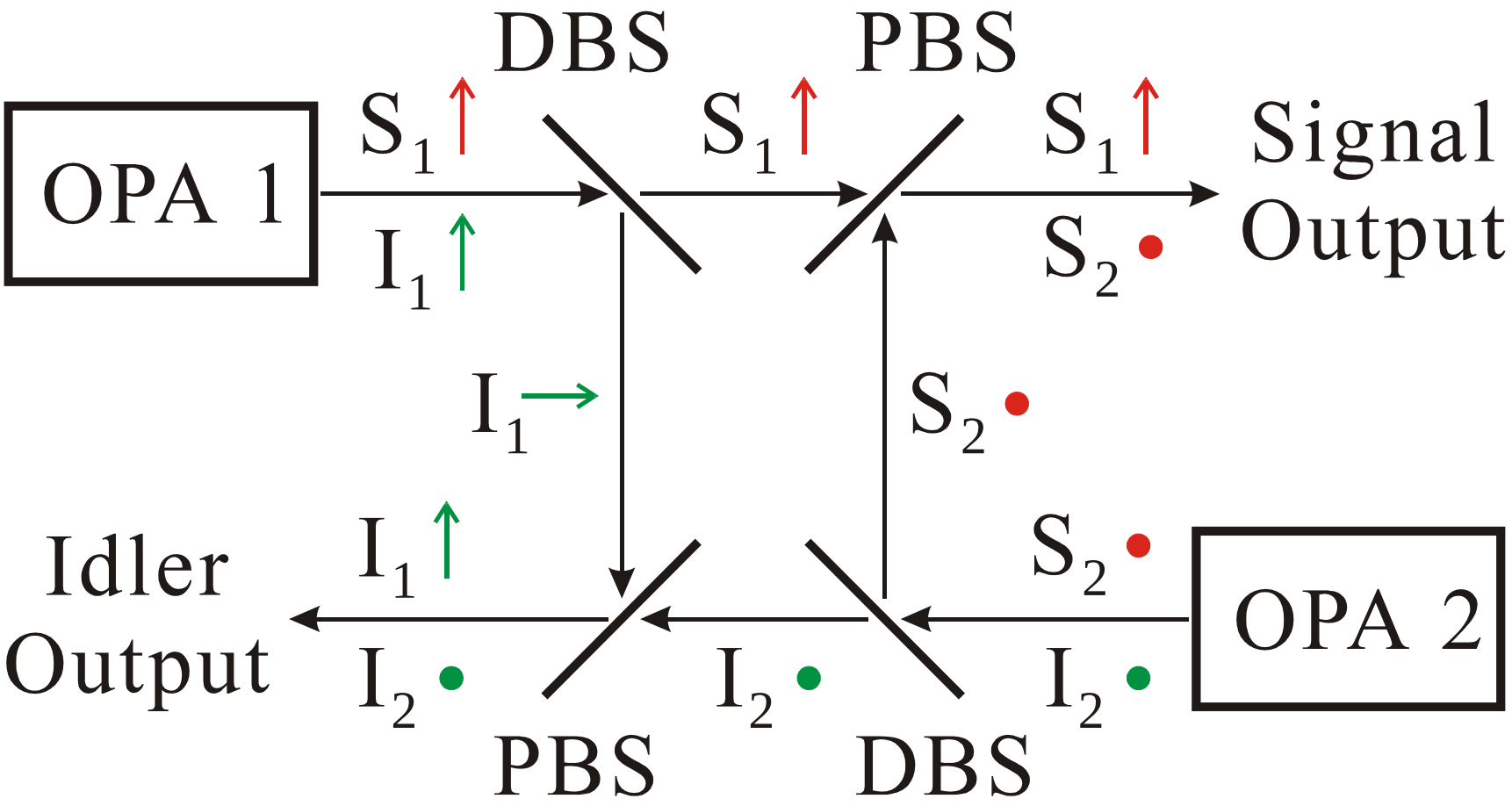
- Type-II phase matched 1-cm-long PPKTP
- Output coupling = 10%, free spectral range = 3 GHz
  - cavity lifetime $\tau_c \approx 7$ ns
  - detection time bin $T = 10\tau_c \approx 70$ ns
  - 1 polarization-entangled photon pair per 700 ns
- 10^5 times brighter than downconversion sources

Periodically Poled KTP



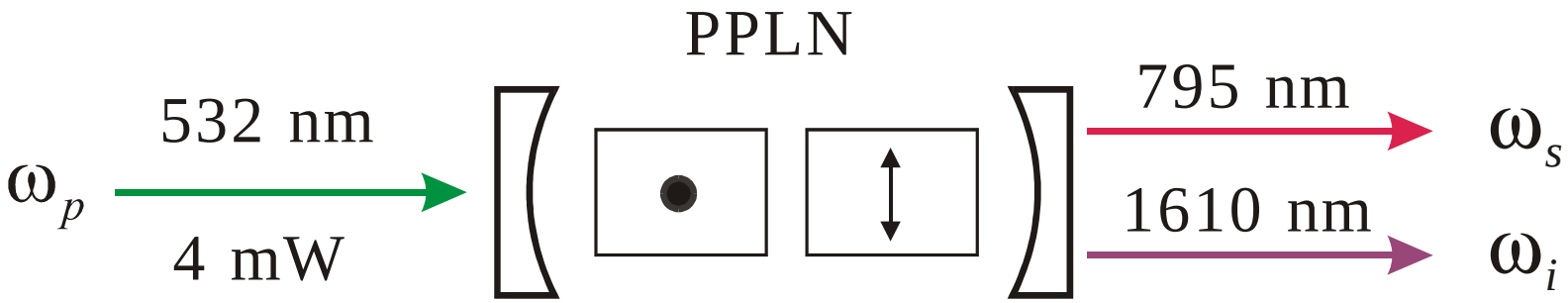
- Quasi phase matching (QPM)
  - $\Delta k = k_3 - k_1 - k_2 \neq 0$
  - grating period $\Lambda = 2\pi/\Delta k$ (typically 10 μm)
- PPKTP: type-II QPM
  - $d_{eff} = (2/\pi)\, d_{24} = 1.8$ pm/V $\quad\quad \Lambda = 8.9$ μm

Type-I Dual-OPA Entanglement Source



Shapiro & Wong, J. Opt. B **2**, L1 (2000)

Type-I PPLN Dual-OPA



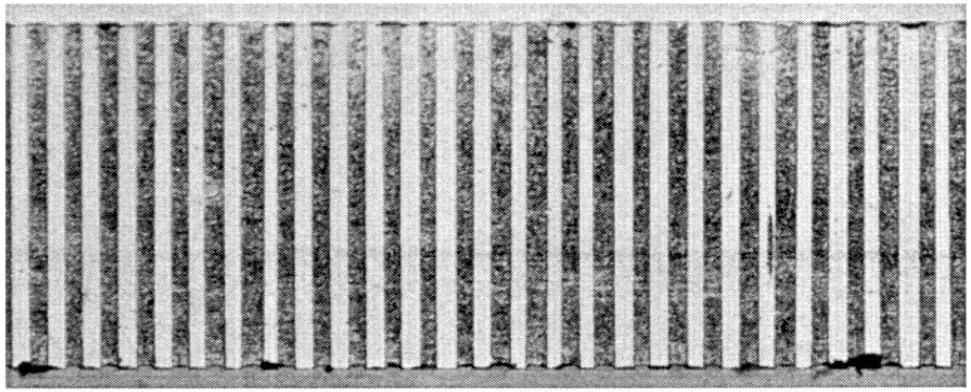
1% of threshold

$1.5 \times 10^6\ s^{-1}$, 30 MHz BW

- Type-I phase matched 5-mm-long PPLN
- Output coupling = 5%, free spectral range = 6 GHz
  - cavity lifetime $\tau_c \approx 7$ ns
  - detection time bin $T = 10\tau_c \approx 70$ ns

PPLN Fabrication

Λ = 22 μm sample length = 10 mm



- PPLN requirement for dual-OPA system:
  - type-I phase matching (same polarization)
  - $d_{eff} = (2/\pi)\, d_{33} \approx 15$ pm/V
  - Λ = 7.5 μm for 532 nm $\rightarrow$ 795 nm + 1610 nm

Quantum Information Technology: Ultrabright Entanglement Source

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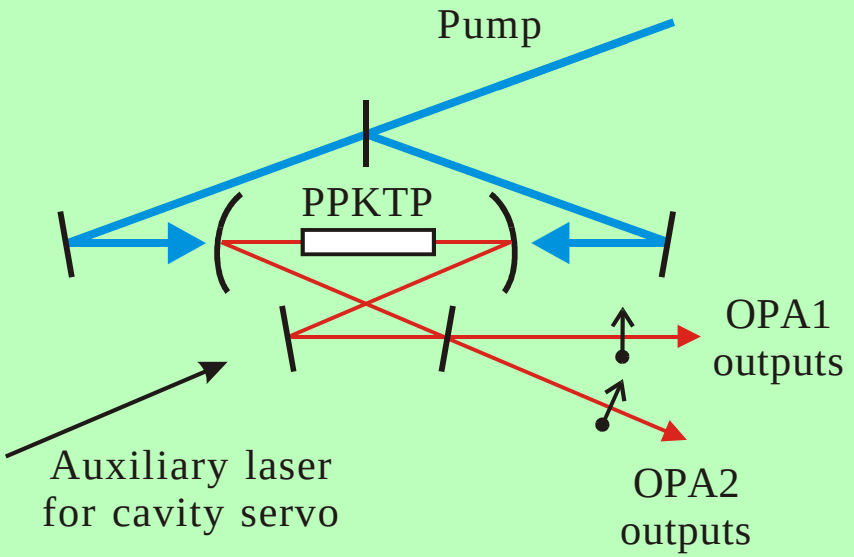
Objectives:

develop a high-flux polarization entanglement source for long-distance singlet-state quantum communications



Program Elements:

- PPKTP dual-OPA source at 795 nm
- PPLN dual-OPA source at 795 nm and 1610 nm
- PPLN dual-OPA source at 1.55 μm
- Entanglement transmission over standard telecom fiber

Schedule: