Energy entangled photonic qudits
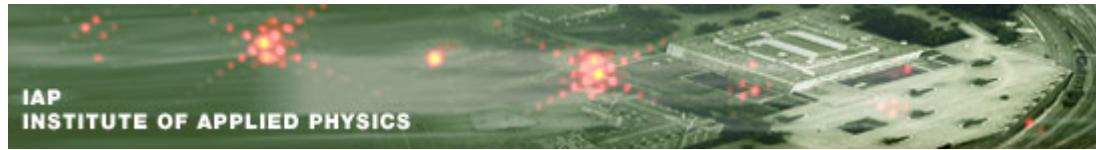
André Stefanov
University of Bern
Institut of Applied Physics
andre.stefanov@iap.unibe.ch

IAP
INSTITUTE OF APPLIED PHYSICS

Laser Physics (T. Feurer)
- **Linear and Nonlinear THz Science (T. Feurer)**
- **Optical Fibers and Fiber Lasers (V. Romano)**
- **Short-Wavelength Plasma Radiation (D. Bleiner)**
- **Soft X-Ray Laser (J. Balmer)**
- **Ultrafast Molecular Spectroscopy (A. Cannizzo)**
- **Quantum Optics (A. Stefanov) since 2012**

SNF-Professor
André Stefanov

Post-doc
Bänz Bessire

PhD Students
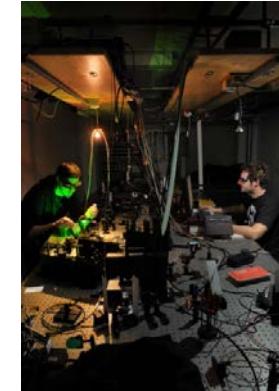Stefan Lerch
Sacha Schwarz

Master Student
Manuel Unternährer

Quantum Optics Lab: Activities

Interaction of matter with entangled photons
- Sum Frequency Generation in non-linear crystals
- Scattering of light in complex media
- Entangled two photon spectroscopy

Quantum Metrology with high flux of entangled photons
- Dispersion measurement, Quantum imaging

Quantum Information
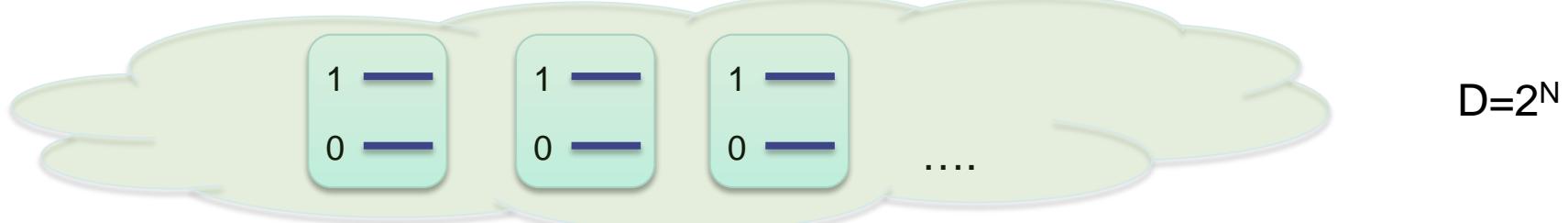- Generation and manipulation of high dimensional entanglement

Metrology (with METAS)
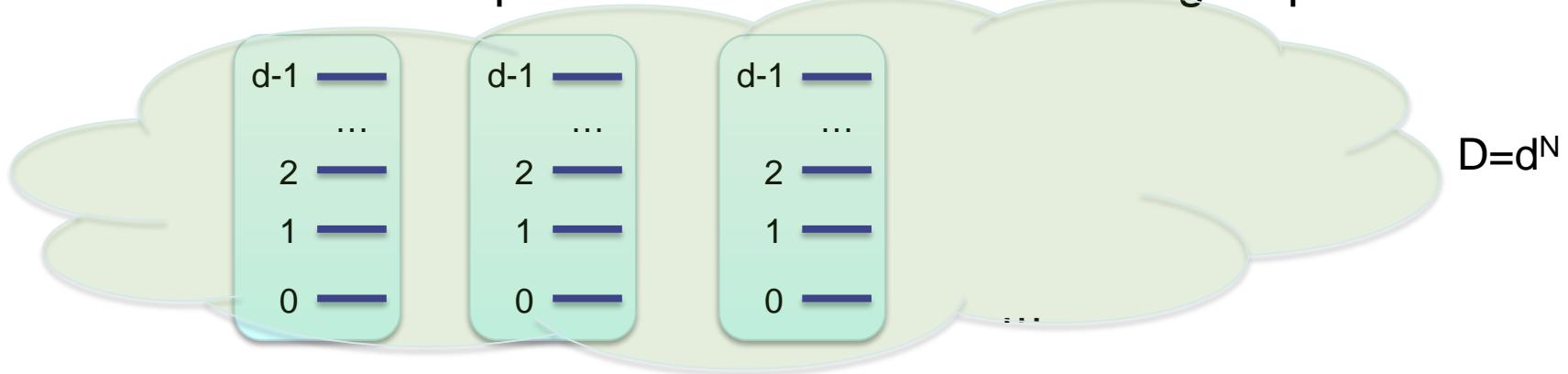- Primary frequency standard

Photonic entangled states

Complex tasks require manipulation of high dimensional entangled states

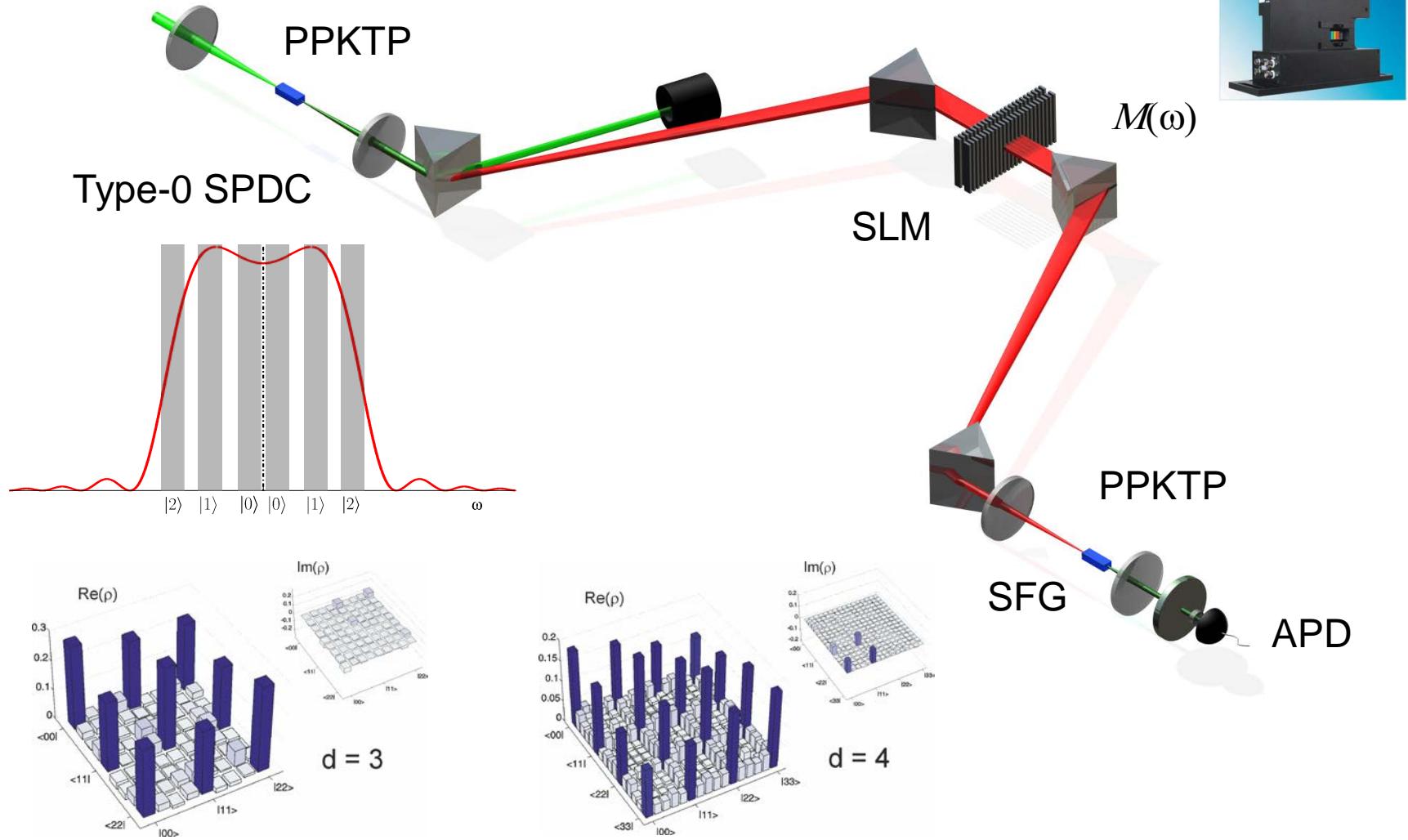1. Increase the number of entangled particles

$D=2^N$

2. Increase the space dimension of each entangled particle

$D=d^N$

Entangled photonic states from SPDC
- Polarization (d=2)
- Transverse modes (d$\cong$50)
- Energy modes (d $\cong 10^6$)

Energy-bin entangled photonic qudits

Bernhard, C., Bessire, B., Feurer, T., & Stefanov, A,. PRA, 88(3), 032322 (2013).

Towards higher dimensons entangled states

Improvement of the experimental setup (ongoing work)
- Improved shaper ⟶ Higher dimensions ($d \cong 40$)
- New photon pair sources and detection schemes

Applications of qudits for quantum information (Theory)
- Advanced tomography
- Quantum protocols

Further steps (Experiment)
- Extension to multi-photon states
- Combine with other modes (hyperentanglement)
- Very large entangled photonic states