First Endless Optical Polarization and Phase Tracker

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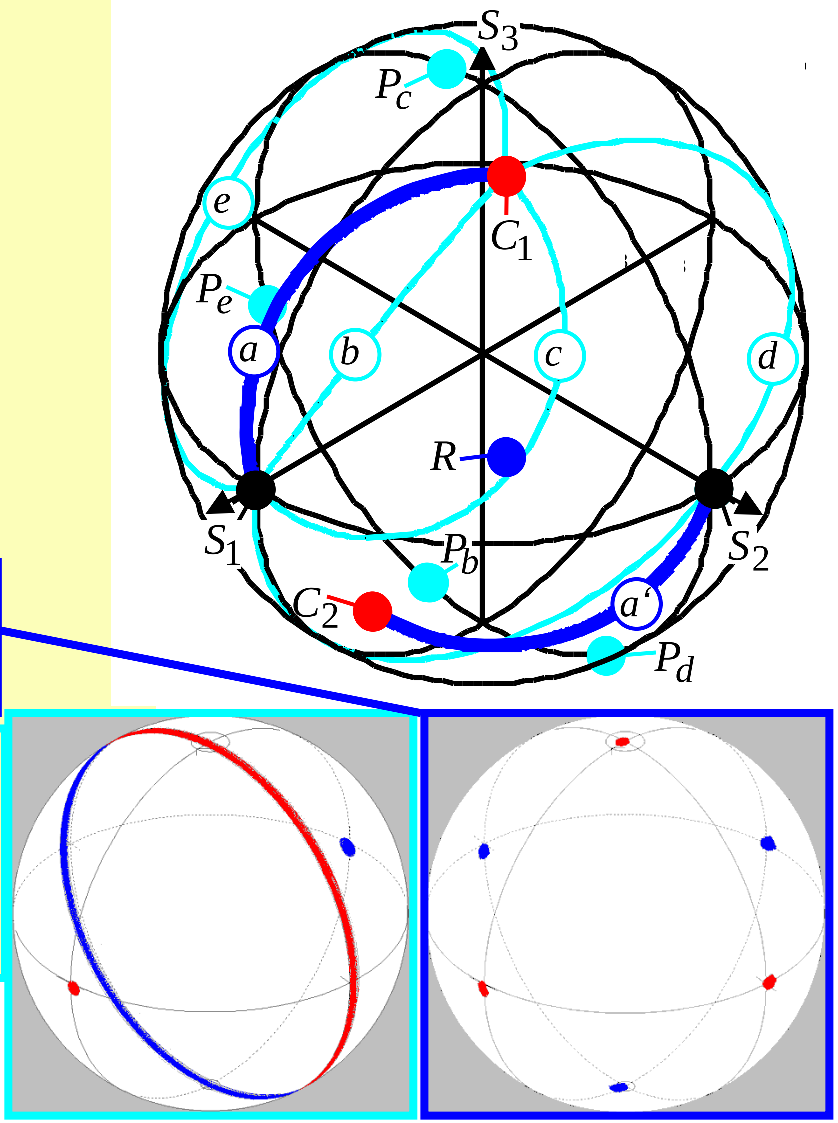
Application areas for simultaneous polarization & phase control/tracking

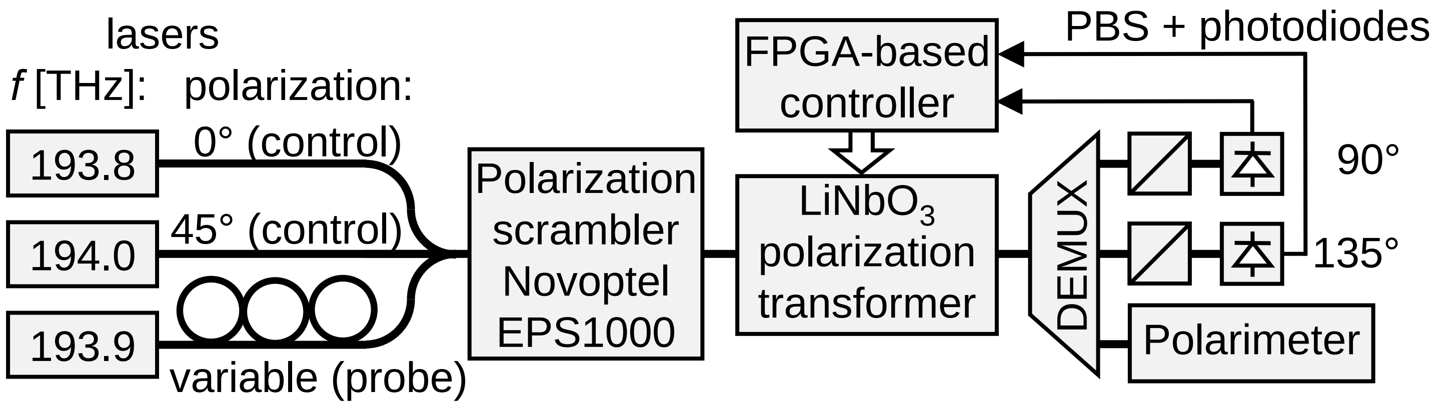
- If **phase difference** of controlled polarization and its orthogonal is also controlled, then the whole normalized Stokes vector space will be stabilized.
- For the BB84 protocol of quantum communication, 0°/90° <u>and</u> 45°/-45° linear polarizations must be preserved.
- Phased arrays require polarization control & **absolute phase** control in each tap or channel.

Control principle with 3 degrees-of-freedom

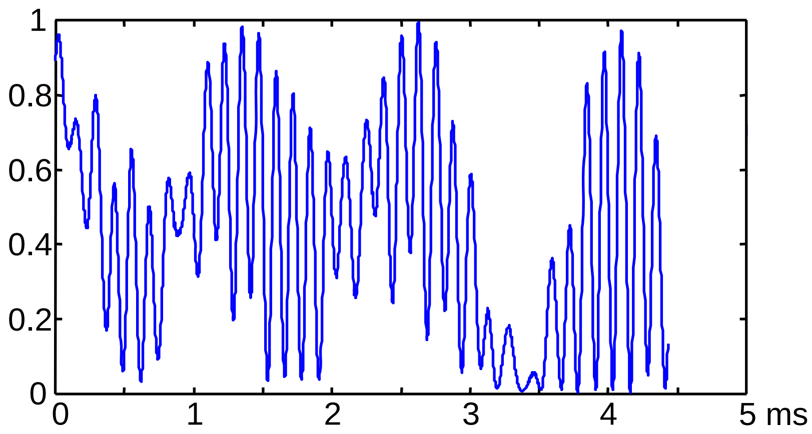
- Not only 1 polarization C_1 is to be transformed into S_1 but simulataneously a 2nd, „semi-orthogonal" polarization C_2 into S_2.
- To achieve this, the phase shift between C_1 and its orthogonal polarization $-C_1$ must be controlled in addition to the polarization transformation of C_1.
- Solution: By rotation about R, C_1 is turned via a into S_1 and C_2 via a' into S_2.
- Conventional, not sufficient: $b...e$ also turn C_1 into S_1, but C_2 is transformed into $P_b...P_e$, hence anywhere on the S_2-S_3 great circle.



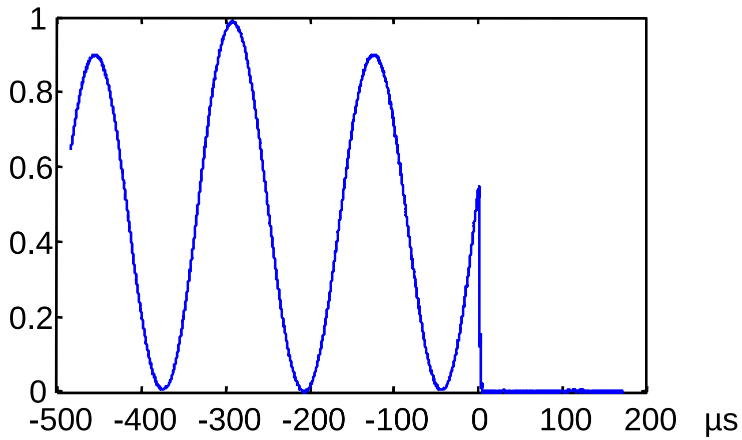
Setup for polarization & phase control (3 degrees-of-freedom)



- 2 „semi-orthogonal“ control signals required
- 2 feedback signals: Signal intensities behind 2 polarizers

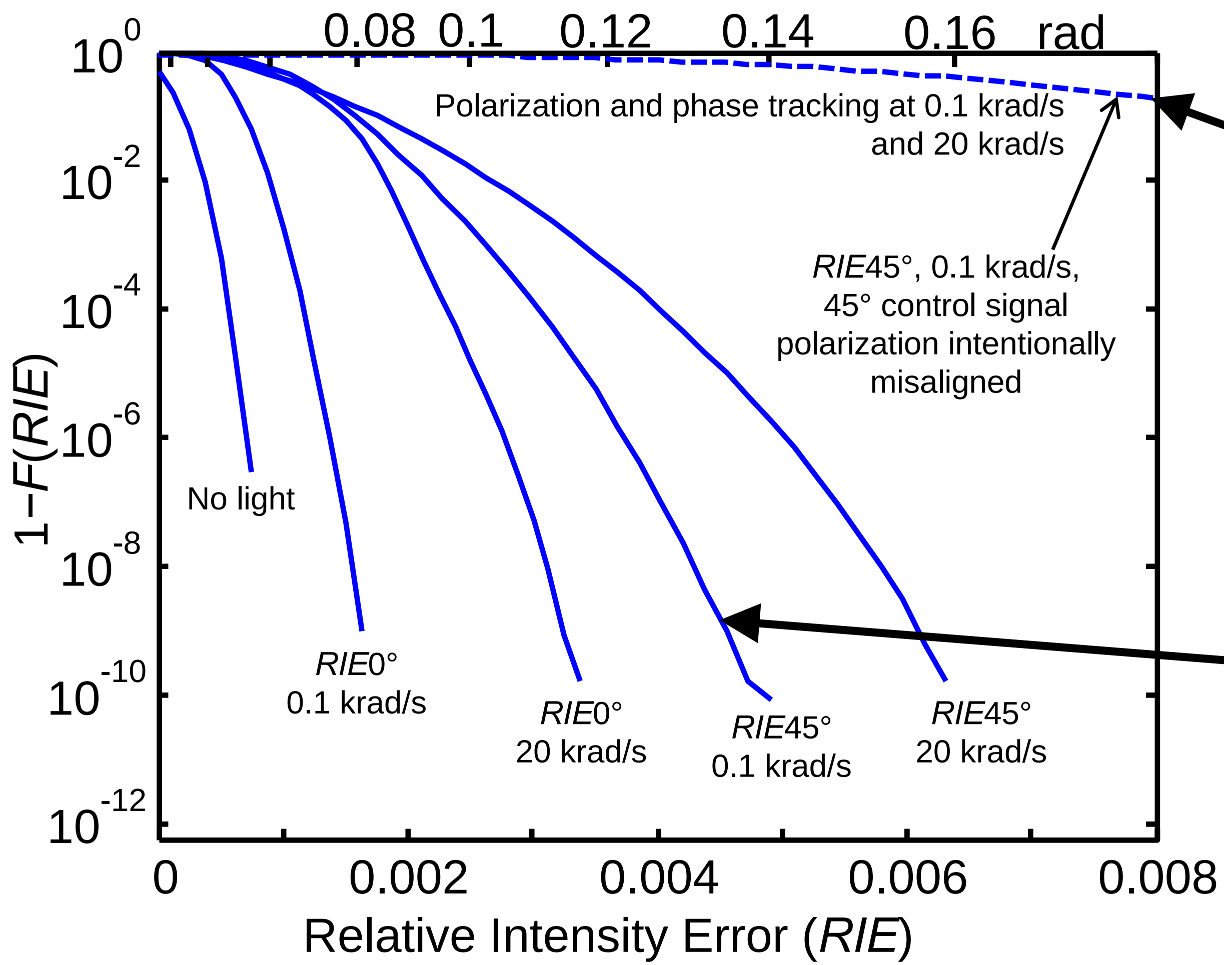


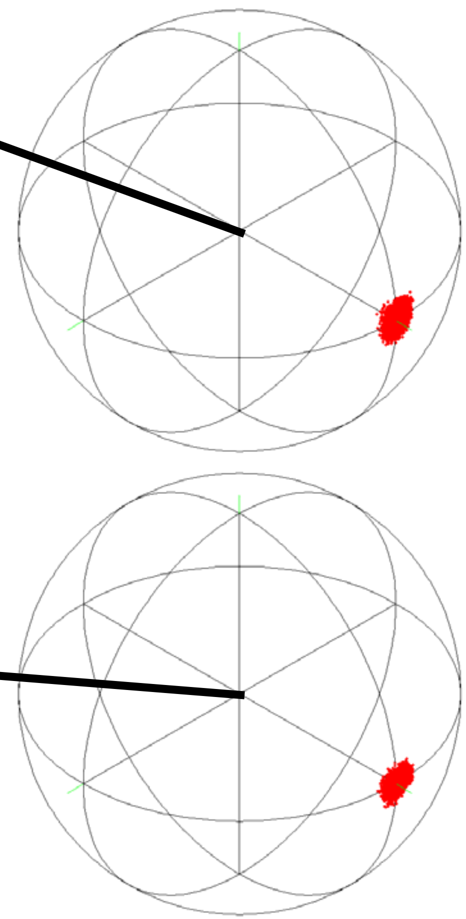
Feedback signal without control



Feedback signal with control switched on

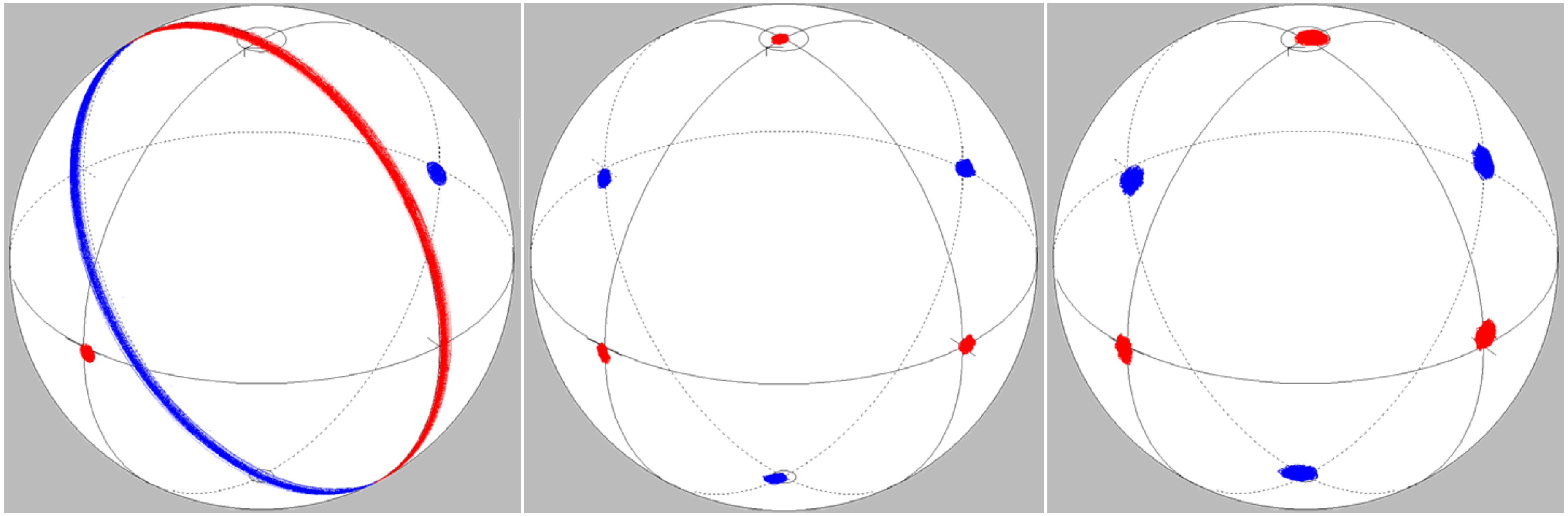
Complementary cumulative distribution function 1-*F*(*RIE*) of relative intensity error (*RIE*) for different scrambling speeds





50 MS/s polarimeter

Poincaré sphere displays of probe signal, set to 6 polarizations on normalized Stokes space axes



Conventional polarization control

Polarization & phase control, 0.1 krad/s

Polarization & phase control, 20 krad/s

As per 1-*F*(*RIE*): max mean errors [rad] of 0° control signal	Polarization & phase control, 0.1 krad/s	Polarization & phase control, 20 krad/s
max	0.08 rad	0.12 rad
mean	0.04 rad	0.06 rad

Discussion, Conclusion

- Portation and preservation of Stokes space from transmitter to receiver
- Polarization & phase reliably stablilized even at 20 krad/s polarization scrambling:
  0.12 rad max, 0.06 rad mean error
- Errors at low scrambling speed:
  0.08 rad max, 0.04 rad mean
- Probe polarization error at low scrambling speed dominated by PMD (25 fs + 30 fs $\Rightarrow$ up to 0.035 rad)
- Applications
  - Phased arrays with polarization & absolute phase control
  - BB84 protocol of quantum communication