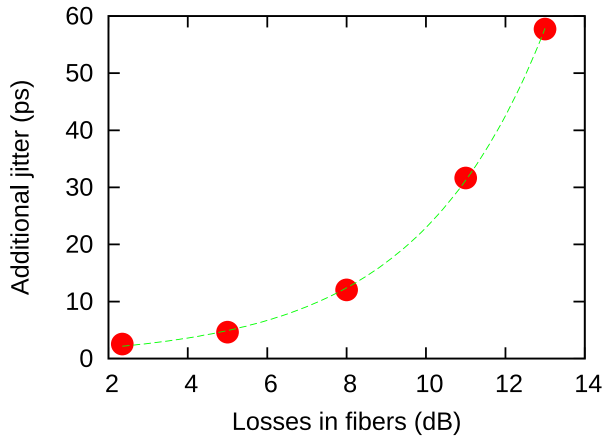


FIG. 8: Additional jitter as a function of fiber loss.

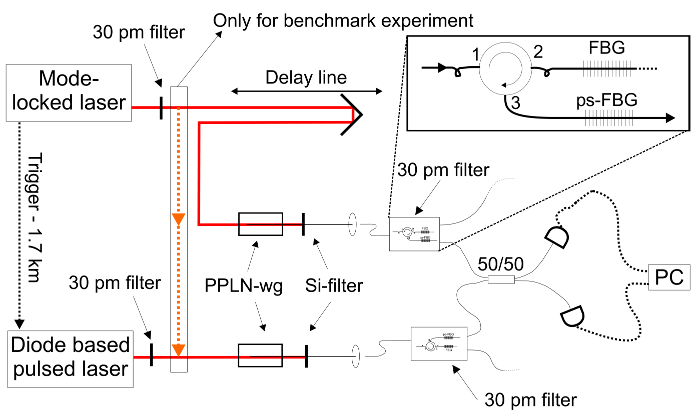


FIG. 9: Experimental setup used to measure a HOM dip with independent sources. The photons combine at the 50/50 beamsplitter and will bunch depending on the delay line.

lization may be required. For 36 km, for example, fibre length would have to be measured and stabilized every 6 minutes, compared to every second if we were to use a femtosecond source, which is a clear advantage.

## 4. PRODUCTION OF UNDISTINGUISHABLE PHOTON PAIRS

We can use these pulsed lasers and spontaneous parametric downconversion (SPDC) to create undistinguishable photon pairs useful for quantum communication. We can then check undistinguishability by performing a HOM dip [27].

The setup for the HOM dip (Fig. 9) consists of the same two synchronized lasers as used for the cross-correlation measurements. The light from these lasers is sent into PPLN waveguides in order to produce pairs of photons using SPDC. The generated paired photons are then collected into optical fibers, spectrally filtered and separated.

In any case the coherence length and therefore the pulse length of the created photon pairs must be larger than the length of the pump pulse that generated them [28]. Our pump pulses were filtered using a 30 pm bulk bandpass filters (Layertec), enlarging them to a 29 ps coherence time, slightly above their original durations, to make them Fourier-transform limited and ensure time-bin entanglement.

To separate signal and idler photons out of each photon pair generator, we use filtering stages made of standard fiber optic components (AOS Gmbh), i.e., the combination of a fiber Bragg grating (FBG) reflecting the desired wavelength of 1548 nm within a large bandwidth, a circulator and a phase shifted FBG as depicted in the inset of Fig. 9. The latter FBG features a 30 pm large transmission peak at 1548 nm from its otherwise broadband reflexion. Two such filtering stages, one at the output of each photon pair source, are employed and fine-tuned so as to match each other using thermal expansion. The signal photons spectrally filtered that way show a resulting coherence time of 117 ps. Note that the idler photons, around the wavelength of 1552 nm, are not used in this experiment.

These indistinguishable signal photons are then sent to a beamsplitter. The variable delay is scanned and coincidence count rates recorded.

## 5. EXPECTED VISIBILITY

The visibility of the resulting HOM dip will be a measure of the undistinguishability of the photons produced. The effect of jitter on the visibility is given by eq. 1, calculated in the appendix, and depends on $\mathrm{r_j}$, the FWHM of the distribution of the timing jitter, in units of the coherence length.

$$\overline{V} = \frac{1}{\sqrt{1+\frac{1}{2}r_j^2}} \tag{1}$$

This result shows a clear decrease of the visibility as a result of time-of-arrival jitter (Fig. 10). It also shows that a small non-zero value of $r_j$ can be tolerated without a dramatic loss of visibility. In our case, considering the pump pulse length of 29 ps and the synchronization jitter of 27 ps, the total timing jitter is 50 ps. With a coherence length of 117 ps, we expect a visibility of 96%. The visibility of a HOM dip directly indicates the maximal visibility that can be obtained in an entanglement swapping experiment.

If we consider Fourier-transform limited gaussian pulses, the coherence length $l_c$ is given by [29]

$$l_c = 0.44 \cdot \frac{\lambda_0^2}{\Delta\lambda}, \tag{2}$$