Manual

Sagnac source for entangled photons

Alessandro Fedrizzi, June 2008

Initial set up

Part List:

- 2 mirrors, dual-wavelength AR coating, angle of incidence **22.5°**
- Dual-wavelength PBS, on a prism or equivalent mount
- Dual-wavelength HWP mounted in rotation stage (no tilting required) set to 45°
- Crystal
- Dichroic mirror (DM), AR coated for the pump, HR coated for SPDC light
- 2 fiber couplers

The first step is to mount all components. Set up the Sagnac interferometer (SI) provisionally to check the space requirements. Due to the many components in the SI, the optical paths for the pump laser focusing and the fiber coupling can get quite long, which may present a problem if one wants to achieve small spot sizes (<100µ) in the crystal. Figure 1 illustrates this:

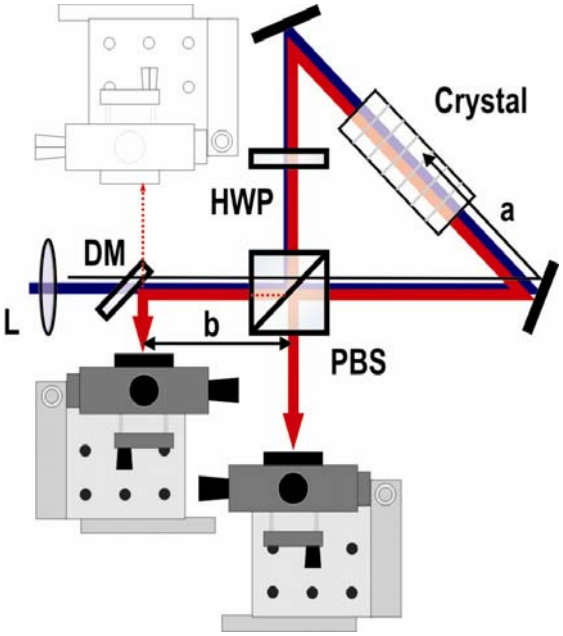

Figure 1: The SI size is governed by the mounts of the PBS, the crystal and the HWP. The distance a from the last pump laser focusing lens (L) is usually fixed if a certain waist has to be achieved. However, path a obviously has to be larger than the distance from the dichroic mirror (DM) to the crystal center. The individual optical paths from the crystal center to the two fiber couplers should be equally long for good mode overlap. Placing the couplers presents a problem. They are very bulky – so the distance b between the DM and the PBS cannot be made much smaller than the physical size of the coupler. Alternatively, if the breadboard allows it, the DM can be flipped and the left coupler placed on the opposite side of the pump beam. This could make the alignment of the setup awkward though.

Once the space requirements have been worked out, start with a beam spot focused to the required size at a known position. The first components that are mounted are the DM and the PBS. Check the angle of the DM by looking at the stray pump light reflected off the back side – it should be at 90° to the pump and stay at the same height. The same principle applies for the alignment of the PBS.
The HWP, optical axis set to 45° can now be added. The mirrors should be placed at equal distance to the PBS. Prealignment of the SI is accomplished by adjusting either mirror such that the beam reflected by that mirror hits the second mirror across the SI at exactly the spot where the other half of the beam impinges. In other words, the part of the pump beam that propagates clockwise in the SI is steered with the upper mirror to hit the mirror on the right at

the same position as the counterclockwise beam. Vice versa, the counterclockwise beam is steered with the mirror on the right such that it hits the upper mirror at the position where the clockwise pump beam impinges.
The fiber couplers are now placed. If they were prealigned, it should usually be enough to remove the longpass filters and adjust the couplers to the stray pump light that exits the PBS through the lower port and to the dim reflection of the DM. If this does not work out, simply shine an alignment beam from the fiber couplers into the SI and adjust the coupler to hit the pump laser spots at the laser mirrors in the SI.
Insert the crystal. The exact positioning inside the SI is not critical, a measurement with a ruler should be sufficient. A neat trick is to use the PBS line along the joint of the two PBS wedges to find the center of the SI (given that the mirrors were placed at equal distance to the PBS).

Now, you should be able to observe single counts. If not, return to adjusting the Sagnac mirrors and fiber couplers. Then proceed to the alignment on coincidences.

Alignment of the Sagnac source

Method 1:

Once single-photon counts are observed in both fibers, rotate the pump beam via the laser HWP and QWP (not shown in the figure) such that *either* clockwise or counterclockwise arm of the SI are fully illuminated (laser polarization H or V). Walk both fiber couplers (translation and angle) until a maximum of single photons is coupled in.

Next, rotate the laser state by 90° to illuminate the other arm in the Sagnac interferometer. As the two Sagnac arms do not fully overlap yet, the single counts in both couplers should now usually be lower or even have vanished completely. Note the current x-y position of the couplers and try to find the counts coming from the second Sagnac arm again by translating one coupler in x and y. The relative change in position from the first arm to the second should roughly be the same for both fiber couplers.

Once you know the positions for maximal single counts in both couplers for the second Sagnac arm, set the couplers to the *centre* of the optimal x and y positions for arm 1 and 2. Then, maximize the singles and coincidence counts by iteratively adjusting the Sagnac mirrors (see figure 2).

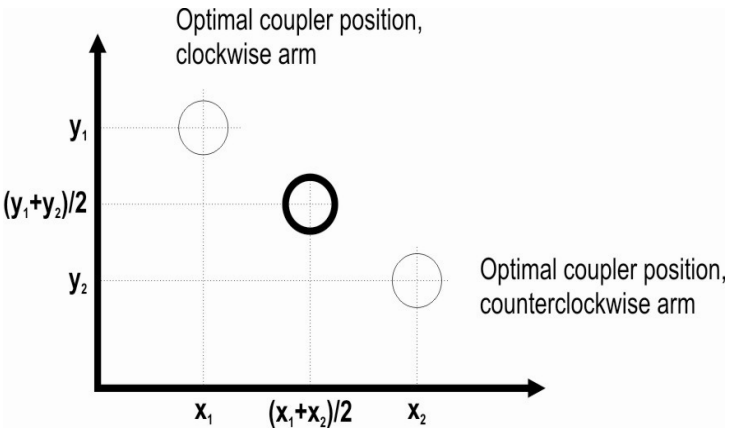

Figure 2: The Sagnac arms will not perfectly overlap after prealignment. Search the optimal coupler positions [(x1,y1), (x2, y2)] for both arms by rotating the laser polarization to illuminate either one arm of the SI and maximizing the single-photon count rates. Then set the couplers to the center of those positions and maximize the count rates via iterative adjustment of the Sagnac mirrors.

The quality of alignment (=overlap of the two SI arms) can be verified via the remaining degree of polarization of the single photons. Rotating the pump polarization should not result in a change of more than 5% in the single count rates. Then the two SI arms overlap, the singles are unpolarized and one should be able to prepare a high quality entangled state.

Usually the above steps have to be repeated a few times. Once the Sagnac mirrors have been adjusted, the coupler positions have to be optimized again and so on. In case that no further improvement can be made, the Sagnac mirrors can be walked (tilt one mirror slightly about the x-axis and recover with the second, repeat for y axis)

Method 2:

Prealign the SI while monitoring the pump laser output of the PBS (remove HWP). Once the two counter-propagating beams in the SI overlap sufficiently, there should be fringes in the far field pattern. You can try to maximize the interference visibility by adjustment of the SI mirrors.
Adjust one of the SPDC output couplers to obtain a maximum of pump light at the fiber output (longpass filters removed).
Shine IR light from a laser diode back through this coupler and maximize the coupling into the second coupler.
Put back HWP – now the two couplers should see pairs and only minor fineadjustments (see fig. 2) are needed in order to obtain high ciunt rates and a balanced SI.