

Squeezing Lab Manual

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1 Introduction

Optically squeezed states of light produced by nonlinear interactions in periodically poled (pp) crystals are specially engineered low-noise states for which the uncertainty in the experimentally relevant (phase or amplitude) variable is brought below the quantum limit. Currently, they are used to improve on the sensitivity of precision metrology experiments such as gravitational wave detection, quantum communication, bio-sensing and computing. To date, the highest levels of squeezing are achieved by encompassing the nonlinear crystal in a cavity making the implementation complex and bulky. The spectral squeezing performance is also limited by the bandwidth of the optical cavity. The difficulty of producing large bandwidth, high levels of squeezing suited for these precision metrology experiments is compounded by the challenge of preserving the squeezing without introduction of added noise.

An alternative to the cavity based approach is to use χ^2 -based waveguide optical parametric amplifiers (OPA) made by periodically poling LiNbO_3 (ppLN) waveguides. These single pass OPA's offer competitive squeezing levels owing to higher non-linearities. These are made possible due to increased efficiency that is a result of higher confinement in a smaller core along the longer, diffraction free interaction lengths.

2 Mathematical frame work for second harmonic generation

The focus throughout this lab work is on the processes based on the χ^2 susceptibility, which was used for the generation of squeezed states and second harmonic generation. A common feature of these processes is that it involves the interaction of three modes of light (or photons), thus the χ^2 processes are known as three-wave mixing processes.

In case of the second harmonic generation (SHG) two photons at frequency ω are absorbed by the nonlinear material to re-radiate a single photon at frequency 2ω . This χ^2 interaction is called up-conversion.

A requirement for SHG is the conservation of energy throughout the conversion process. In other words,

$$\omega_i + \omega_s = \omega_p \quad (1)$$

has to be satisfied. In nonlinear optics, this conservation of energy is often referred to as phase matching. The phase matching condition for SHG is satisfied when

$$\frac{n_i \omega_i}{c_0} + \frac{n_s \omega_s}{c_0} = \frac{n_p \omega_p}{c_0} \quad (2)$$

where, n_x is the refractive index of the nonlinear medium experienced for the idler, signal or pump field and c_0 is the speed of light in vacuum. There are several kinds of techniques available in literature such as refractive index phase matching, polarisation phase matching. However, for the purposes of this lab, we will focus on quasi phase matching (QPM). QPM is done via a periodic manipulation of the cumulated relative optical phase in the crystal. In this technique, where the crystal's domain is inverted periodically on short length scales. With this technique, one does not require the refractive index for the fundamental and harmonic to be equal any more as it results in the ability to achieve phase matching at almost room temperatures over a very wide temperature range compared to the other methods mentioned in literature. Another added advantage here is that materials with higher intrinsic nonlinearities can be used, which are otherwise unreachable with temperature or angle tuning.

The first step for the generation and detection of squeezed light comes from the up-conversion of the 1550 nm source to 775 nm through SHG as seen in figure 3. We model the generation of SHG (and also squeezing) in waveguides starting from coupled mode equations. Denoting the electric field of 775 nm light as B and the electric field of 1550 nm light as A the coupled mode equations are expressed as:

$$\frac{dA}{dz} = i \frac{\sqrt{\alpha_{SHG}}}{L} B(z) A(z)^* e^{i\Delta k z} \quad (3)$$

$$\frac{dB}{dz} = i \frac{\sqrt{\alpha_{SHG}}}{L} A(z)^2 e^{-i\Delta k z} \quad (4)$$

where α_{SHG} is the second harmonic generation (SHG) conversion efficiency in units of W^{-1} , L is the length of the waveguide, and Δk is the wavenumber mismatch. Assuming perfect quasi-phase matching (QPM), the wavenumber mismatch becomes zero ($\Delta k = 0$).

If we assume perfect QPM and calculate the power of the SHG light by solving equations 3 and 4 we get:

$$P_{SHG} = P_{in} \tanh^2(\sqrt{\alpha_{SHG} P_{in}}) \quad (5)$$

where $P_{in} = |A|^2$ is the input 1550 nm light and $P_{SHG} = |B|^2$ is the generated SHG light.

If we don't assume perfect QPM ($\Delta k \neq 0$), as in equation 5, the solution to equation 3 and 4 is instead:

$$P_{SHG} \propto P_{in} L^2 \text{sinc}^2\left(\frac{\Delta k L}{2\pi}\right) \quad (6)$$

where, again, P_{in} is the the input 1550 nm light and P_{SHG} is the generated SHG light. The SHG efficiency is in this case dependent on the wavenumber mismatch and we find maximum SHG efficiency at perfect QPM ($\Delta k L = 0$) and no SHG at $\Delta k L = 2\pi n$. Both the refractive index and the length of the waveguide can be assumed to be linearly dependent on temperature changes:

$$\Delta k L = b(T - T_0) \quad (7)$$

with b being an arbitrary constant. The SHG efficiency is thus dependent on the temperature and we can now rewrite equation 6 as:

$$P_{SHG} \propto P_{in} A \text{sinc}^2(b(T - T_0)) \quad (8)$$

with A and b being arbitrary constants and T_0 the optimal phase matching temperature, which all can be found experimentally. Hence, temperature fine tuning is required for satisfying the phase match condition.

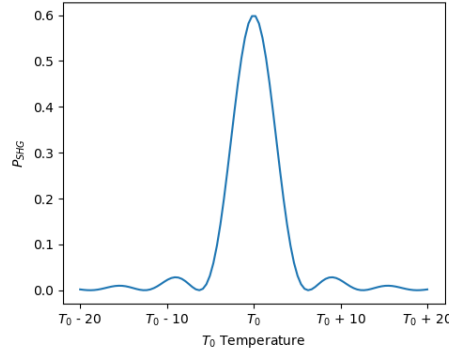


Figure 1: SHG dependence on the temperature.

3 Mathematical framework to estimate squeezing

The second step in this mathematical framework is to generate the squeezing in the OPA. For this we consider the 775 (B) and 1550 nm (A) light as an average amplitude along with small quantum fluctuations as:

$$B = \bar{b} + \delta \hat{b} \quad (9)$$

$$A = \bar{a} + \delta \hat{a} \quad (10)$$

Rewriting the coupled mode equations for the OPA assuming no input 1550 nm light ($\bar{a} = 0$), an undepleted pump ($\bar{b} = \text{const.}$), and that the pump power is much larger than the vacuum fluctuations ($|\bar{b}| \gg \delta\hat{a}, \delta\hat{b}$), we get the equation:

$$\frac{d\delta\hat{a}}{dz} = i \frac{\sqrt{\alpha_{SHG}}}{L} \bar{b} \delta\hat{a}^\dagger \quad (11)$$

where α_{OPA} is the squeezing efficiency. In principle α_{OPA} is the same as α_{SHG} , but we remark them here as different as in general the SHG and the OPA waveguides have different conversion efficiencies. Typically one would always measure α_{OPA} by considering the SHG conversion efficiency instead of the squeezing efficiency, as the former is much easier to measure.

The amplitude and phase noise quadratures are defined through the quantum field fluctuations $\delta\hat{a}$ as:

$$\delta\hat{X}_+ = \delta\hat{a} + \delta\hat{a}^\dagger \quad (12)$$

$$\delta\hat{X}_- = i(\delta\hat{a} - \delta\hat{a}^\dagger) \quad (13)$$

The $-$ and $+$ signs on the quadratures indicate that we will be squeezing in the phase quadrature and anti-squeezing in amplitude quadrature, which is done by setting the phase of $\bar{b}$ to $-\frac{\pi}{2}$. Using equation 11, 12, and 13 the equations for the quadratures becomes:

$$\frac{d\delta\hat{X}_+}{dz} = \frac{\sqrt{\alpha_{SHG}}}{L} |\bar{b}| \delta\hat{X}_+ \quad (14)$$

$$\frac{d\delta\hat{X}_-}{dz} = -\frac{\sqrt{\alpha_{SHG}}}{L} |\bar{b}| \delta\hat{X}_- \quad (15)$$

Solving these differential equations and then taking the variance gives the following levels of squeezing and anti-squeezing:

$$V_- = \exp\left(-2\sqrt{\alpha_{OPA}P_{SHG}}\right) = \exp(-2R) \quad (16)$$

$$V_+ = \exp\left(2\sqrt{\alpha_{OPA}P_{SHG}}\right) = \exp(2R) \quad (17)$$

Furthermore, we defined a squeezing parameter, $R = \sqrt{\alpha_{OPA}P_{SHG}}$, which represents the level of squeezing/anti-squeezing generated from a waveguide.

Detection of squeezed light is performed through balanced homodyne detection using a local oscillator (LO) which is tapered off from the same source as the SHG pump. The LO is overlapped with the weak squeezed light on a 50/50 beamsplitter to enhance the signal and the electrical output of the two photodiodes is subtracted. Depending on the relative phase θ between the LO and the squeezed light, the output electrical signal will be:

$$i_- \propto \delta\hat{X}_+ \cos(\theta) + \delta\hat{X}_- \sin(\theta) \quad (18)$$

This then allows to measure anti-squeezing and squeezing depending on the local oscillator phase θ which is shown in 2.

The two primary factors that affect usable squeezing are loss and phase noise. Loss is modelled as a partially transmissive mirror which couples in vacuum fluctuations. Whilst phase noise comes from the inability to precisely match the LO and squeezed light phase. For this lab, we will ignore the effects of phase noise as we won't be able to measure it. Disregarding phase noise, the measured variance is:

$$V_{meas} = \eta(\cos^2(\theta)V_+ + \sin^2(\theta)V_-) + (1 - \eta)$$

where η is the total efficiency and V_- and V_+ is as in equation 16.

The measured variance as a function of θ is shown in figure 2. Here we observe anti-squeezing when θ is a multiple of π and squeezing when the phase is $\pi/2$ or $3\pi/2$.

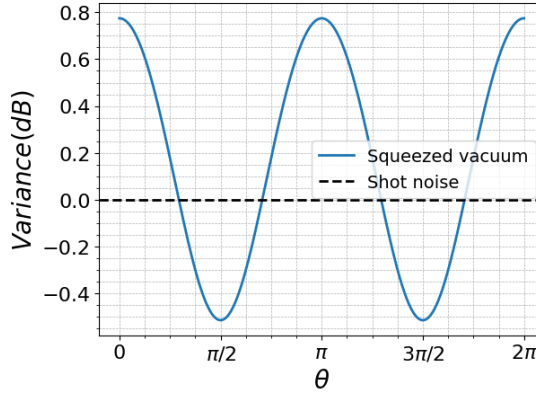


Figure 2: Variance of vacuum as a function of local oscillator phase. We observe squeezing when $\theta = \pi/2$ and anti-squeezing for $\theta = \pi$.

4 Common units used in laser and quantum optics

When working with optical systems the power is usually given in the relative unit dB (decibel). The relative power, in dB, between the measured power P and the reference power P_0 is calculated as follow:

$$P_{dB}[dB] = -10 * \log_{10}\left(\frac{P[W]}{P_0[W]}\right) \quad (19)$$

and from the relative power P_{dB} , the measured power P is calculated as:

$$P[W] = P_0[W] * 10^{-P_{dB}[dB]/10} \quad (20)$$

Another relative measurement unit used is dBm (decibel-milliwatts), which has a fixed relative power to one milliwatt ($P_0 = 1 \text{ mW}$).

$$P_{\text{dBm}}[\text{dBm}] = -10 * \log_{10}\left(\frac{P[W]}{0.001[W]}\right) \quad (21)$$

$$P[W] = 0.001[W] * 10^{-P_{\text{dBm}}[\text{dBm}]/10} \quad (22)$$

Given two power levels in dBm it is easy to express the relative power difference between the levels in dB:

$$\begin{aligned} P_1[\text{dBm}] - P_2[\text{dBm}] &= -10 * \log_{10}\left(\frac{P_1[W]}{0.001[W]}\right) - (-10 * \log_{10}\left(\frac{P_2[W]}{0.001[W]}\right)) \\ &= -10 * \log_{10}\left(\frac{P_1[W]}{P_2[W]}\right) = P_{1-2}[\text{dB}] \end{aligned}$$

5 Safety rules

It is **very important** to obey the following safety rules when the laser source is on as otherwise it can lead to permanent damage to the eyes and skin.

- Always wear protective googles (provided in the lab)
- Put up the warning sign that the laser is on outside the lab to let those outside the lab know.
- Do not wear reflective objects such as rings or watches.
- Wipe down the glasses with the wipes provided with the goggles after the lab is completed.

6 Pre-questions to be discussed with the TA before doing this lab

- Is the measurement of squeezing relative or absolute?
- What does the WDM do in the setup and why is it important?
- If you measure -70 dBm on the spectrum analyser for shot noise and -71 dBm for squeezing. How much squeezing do you have?
- Why do we measure squeezing around MHz frequencies in the spectrum analyser?
- Using the efficiencies in table 1 and 2, as well as a SHG power of 200 mW. How much squeezing do we expect to see?
- Given that $V_{\text{meas},sqz}$ is the squeezing measured and $V_{\text{meas},asqz}$ is the anti-squeezing measured. Which of the following statements are true and explain why:

1. $V_{\text{meas,sqz}} \cdot V_{\text{meas,asqz}} = 1$
2. $V_{\text{meas,sqz}} \cdot V_{\text{meas,asqz}} \leq 1$
3. $V_{\text{meas,sqz}} \cdot V_{\text{meas,asqz}} \geq 1$

7 Details of the experimental setup

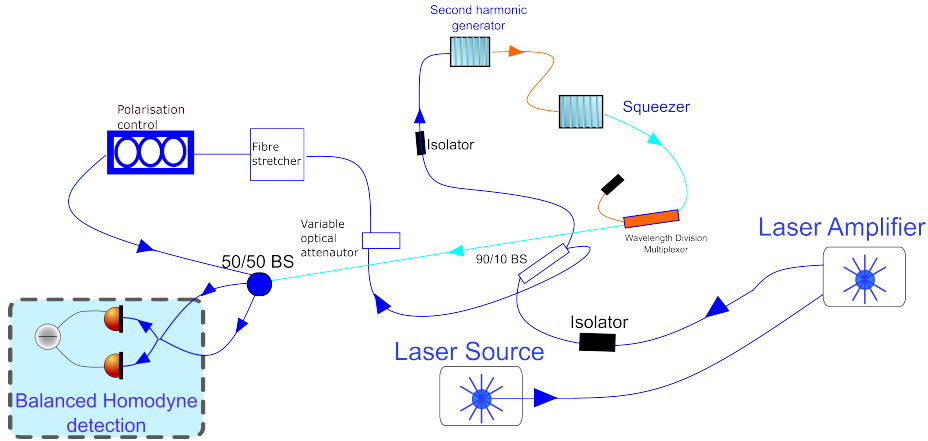


Figure 3: Drawing of the entire squeezer setup.

Figure 3 shows a schematic of the setup. For your lab reports, you are encouraged to use something similar or use the inkscape library. Figure 4 shows a picture of the actual experimental setup to show you the scale of the components. The fiberised components are mounted into holders to prevent excessive bending loss and damage to the fibres. The entire setup is mounted on a floating table to provide some isolation from acoustic noises coupling into the experiment. The squeezer setup in our full scale lab implementations also involves placing the entire setup in a box to prevent air currents from affecting the setup.

Task 0 : Before starting the experiment, familiarise yourself with how fibers and fiberised connectors work! Ask your lab supervisor what the acronyms APC, PC stand for, why are some fibers thinner than others? How do you identify if the fiber is polarisation maintaining or not? How do you clean a fiber connector? Why should you clean the fiber connector?

Laser system : The laser used in the experiment is a single frequency distributed feedback (DFB) fiber laser with emission centred around at 1550 nm (which we have also referred to as the fundamental wavelength) that is being amplified by a low-noise fiber amplifier. Both the laser and the amplifier have an

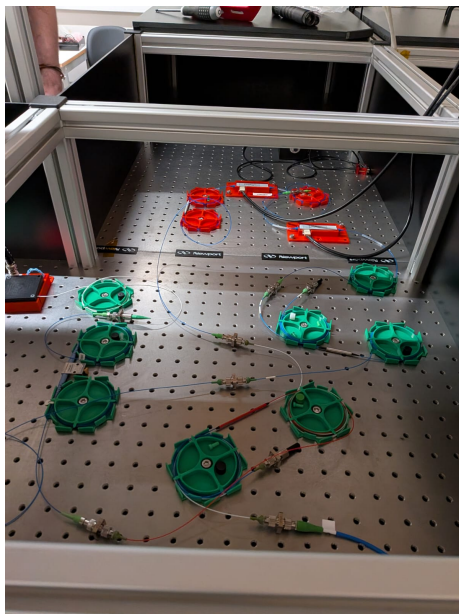


Figure 4: Photo of part of the experimental setup. Closest is the 90/10 BS, farthest up is second harmonic generator and squeezer.

isolator (ISO) immediately after their outputs to prevent back reflections into the laser and amplifier as these can damage the light sources. The amplified laser light is then split into two paths by a 90/10 fiber coupler (FC), with the 10% path being designated to be the local oscillator (LO). The rest enters the nonlinear waveguide chain. The LO path employs a Variable Optical Attenuator (VOA) in order to control and attenuate the light to achieve the desired optical power levels.

Nonlinear stages : The very first nonlinear conversion we observe is the upconversion of the fundamental 1550 nm to 775 nm through second harmonic generation process using a periodically poled Lithium niobate waveguide (SHG in 3). The 775nm-light is then attenuated when needed and inserted into a second periodically poled Lithium niobate waveguide, the 'Squeezer', also referred to as the OPA. This produces squeezed light by the process of spontaneous parametric down conversion. Squeezing here is generated at the fundamental wavelength of 1550 nm. Both waveguides are held to the optimal phase matching point by means of a temperature controller. Be careful when changing the settings on the temperature controller because you might accidentally change the temperature of the wrong waveguide. You may notice another component after the OPA and this is called a wavelength division multiplexer (WDM). This component filters out the SHG that is not converted to squeezed light. If this is not done, it adds additional shot noise to the local oscillator, obscuring the squeezed vacuum signal.

Local Oscillator : The LO path consists of a Fiber Stretcher (FS) that is used to stretch (and shrink) the fiber in order to change the path length of the light and therefore the phase of the LO light. This arm also consists of a polarisation controller (PC) that it used to alter the polarisation of the light field. As some of the components in the LO path are non polarisation maintaining, it is important to make sure that you use the paddles of the controller to match the polarisation of the squeezed states thereby maximising the squeezing level measured. Polarisation mismatch manifests as a loss in the chain thereby leading to lower levels of squeezing. The squeezed light is detected by interfering the LO with the squeezed light on a 50:50 beam splitter and detecting the outputs with a balanced photo detector (BPD).

Balanced detector : The detector you are using is a AC-coupled high-speed dual-balanced InGaAs photodiode from Wieserlabs. The photodiode is designed for low noise operation between 300 kHz to 1 GHz and has a damage threshold of 10 mW. **Do not exceed this power level!** Several trade-off's are to be considered when designing a photodetector and some of these need to be weighted against each other : desired bandwidth, size of the active area of the photodiode, wavelength dependence on the material used. The advantage of generating squeezed light in the continuous variable regime (what do we mean here? :)) is the fact that we can operate this device at room temperature! Is this different from another lab you have done?

Characterisation details of the OPA : In order to model the generated squeezing levels, it is important to know the properties of the components used in the setup. To help you with this, we give you some numbers that you will need in the table 1 and 2 below :

Device	Efficiency
$\eta_{OPA,out}$	0.6
$\eta_{OPA,prop}$	0.9
η_{WDM}	0.77
η_{cables}	0.83
η_{BS}	0.95
η_{PD}	0.8

Table 1: Efficiencies in some of the devices after the OPA.

Device	Value
$\eta_{OPA,in}$	0.5
α_{OPA}	0.764 W^{-1}

Table 2: In-coupling efficiency into the OPA, as well as the squeezing efficiency of the OPA.

8 Performing the Experiment

8.1 Power meter

The integrating sphere is connected Thorlabs Power Meter. Confirm that you have the correct wavelength settings and correct power interval. When switching power head you might need to reset the wavelength to the correct one. The display of the power meter shows you the currently measured power. To do a measurement, either write down the measured values over a period of time (e.g. every 10 sec. for 5 minutes). You can also record the data with the power meter and export it via the USB-connection to your computer. Plot the measured power over time either as a histogram or line plot of power vs. time.

8.2 Fiber handling

Always wear gloves when handling the fibres. Make sure the fiber ends are cleaned before connecting them. NEVER look into the fiber when the laser is on, especially not with the microscope.

8.3 Laser operation

Although all laser light is fiber coupled in this lab it is of utmost importance to always wear googles due to the high optical power involved in the experiment. Thus, if the laser is on, please put on the googles before entering the lab.

The laser and amplifier are controlled by the software CONTROL on the computer, from where the output power can be altered and emission can be turned on or off. The Amplifier can output 2 W, but the waveguides can't handle more than 1 W and therefore you should refrain from using powers more than 1 W from the amplifier.

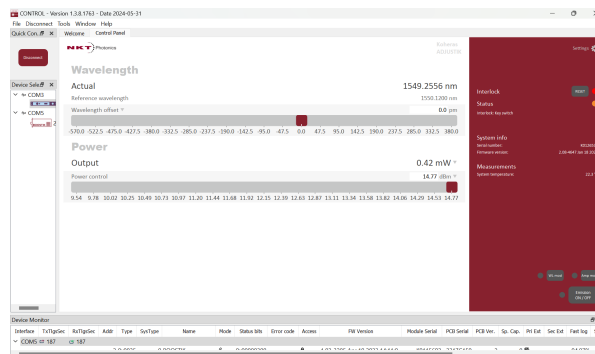


Figure 5: Laser Software

8.4 Waveguide operation

The next part of the experiment involves operation of the temperature controllers, safety guide and rules for operation of the waveguides. Please read this section carefully before performing the experiment. Before doing anything, check which waveguide is connected to which port of the temperature controller and make a note of it! It is important to do this because the temperature of the two waveguides is controlled by means of a single temperature controller (which is capable of establishing two temperature control loops) which in turn is controlled by the computer using the program HCP Controller. To connect to the controller, first press Refresh Serial and then Serial Open once the COM/serial port is found. Once you are certain, you can turn on the temperature control on each port and set the temperature, as shown in figure 6. The waveguides are very sensitive to rapid temperature changes and therefore it is important to change the temperature in **small** intervals, both when heating and cooling. **It is also important that the waveguides should not be heated when having no light inserted, thus they need to be cooled down to room temperature before the laser is turned off or disconnecting. Before closing the software, disconnect the serial port by pressing Serial Close.**

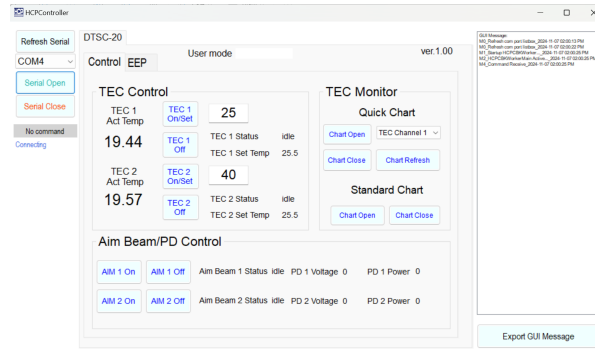


Figure 6: Software for temperature controller.

9 Characterization of the SHG

Task 1 : Measure the fundamental optical power entering the SHG waveguide with the appropriate integrating sphere. How stable is this power over a time scale of 5 minutes? Comment on this in your report. Please do this part with the lab supervisor as it involves high optical powers. Ask yourself why do we use an integrating sphere?

Task 2 : Plot the SHG dependence on the temperature and fit it with an appropriate function. What is the optimal phase matching temperature and the optimal SHG efficiency?

Before disconnecting any of the fibers in the setup, the emission of the laser and amplifier should be turned off.

1. Connect the output of the 90/10 coupler going into the nonlinear arm to the appropriate integrating sphere. Ask yourself how to check which of the integrating spheres on that table you should use where. Also, make sure that the LO arm is not connected to the photodiode but instead is terminated with an optical terminator. This is to prevent damage to the photodiode by accidental high power.
2. Turn on the laser and amplifier and measure the optical power before the SHG. Does it need to be attenuated or can you increase the amplification? Looking at the power output of the amplifier, is the power level you are measuring reasonable? (Task 1)
3. Turn off the amplifier and connect the 90% of the coupler to the SHG. Connect the output of the SHG to the 775 nm integrating sphere and turn on the laser in order to measure the optical power.
4. Turn on the temperature controller and start increasing the temperature of the SHG waveguide in steps, recording the power level at each step. Wait until the power level is stable before recording the data and moving up to the next temperature. You should see the generation of 775 nm light increasing until a certain optimal temperature, from where the power level starts decreasing again. Take measurements until you can resolve "the whole sinc". (Task 2)
5. Decrease the temperature in steps (max 5°) until you reach the optimal temperature again.

9.1 Arbitrary Waveform Generator

Many devices contain an Arbitrary Waveform Generator (AWG) that can output e.g. a sine wave or a linear ramp. You are going to use an oscilloscope for this purpose. Once turned on, press the AWG button to open the settings menu on the display. Here, you set the desired parameters on the touchscreen to generate a signal that is driving the fiber stretcher and thus changing the phase of the local oscillator. Before turning on the output of the AWG, confirm the settings with the lab instructor.



Figure 7: Waveform generator on the oscilloscope.

9.2 Zero span measurement with a Spectrum Analyser

This is a guide on how to do a zero span measurement for squeezing using the Rohde&Schwarz FSV:

1. Set center frequency: Press Freq. Then write e.g 20 MHz. Press enter.
2. Set zero span: Press span → On screen press zero span.
3. Choose resolution bandwidth: Press BW → On screen press RES BW. Choose a reasonable value, e.g 5 MHz. Press enter.
4. Choose video bandwidth: Same screen as BW → On screen press Video BW Manual Choose a reasonable value, e.g 30 Hz. The video bandwidth removes high frequency noise. It needs to be larger than whatever modulation frequency you will have on the fiber stretcher.
5. Sweep time: Press SWEEP → On screen press Continuous sweep, then Sweep Time Manual. Choose a reasonable value, e.g 2 sec. Press enter.
6. Choose scale: Amplitude → Range: e.g. 2 dB This is the vertical range of the full screen.
7. Change reference level: On amplitude, press Ref Level. Use the scroll wheel or input to set a reference level such that the signals can be seen. Typically around -90 dBm for dark noise and around -50 dBm for the shot noise here.
8. Save reference traces: Press TRACE. There are four possible traces, Trace 1 to 4. For each trace you can either write on it, you can blank it (make it invisible on screen) or view it. When you wish to save a trace click on Traces and select "view" in the drop-down menu of the corresponding trace. This freezes the trace. Set a different trace to "Clear Write" to continuously write new data in this trace. Save reference traces so you can distinguish between dark noise, shot noise, and squeezing. It is

also possible to save minimum or maximum value on a trace by selecting "Min/Max hold" in the drop-down menu. This can be useful to get the squeezing and/or anti-squeezing values.

9. Markers: Press Lines. You can use Lines to get the amplitude value of a certain point. Simply choose vertical line 1 or 2 and move it with the scroll wheel. Sadly it's not possible to pause a continuous measurement but it's instead recommended to do a single sweep measurement. Select Single Sweep instead of Continuous Sweep after pressing the Sweep button. This way it is easier to find highest squeezing and anti-squeezing value.

10 Squeezing measurement

Task 3a : Measure the dark noise of the photodiode and the shot noise of the local oscillator. How well separated are these? **Task 3b** : Measure the squeezing arches using the spectrum analyser referenced to the LO shot noise level. What is the maximum squeezing and anti-squeezing that you were able to measure? Why is this antisymmetric? Could you optimise this with polarisation of the LO? How does this compare to the squeezing level that is modelled in the theoretical section of this manual?

Once you've find the optimal phase matching temperature of the SHG waveguide it's time to generate some squeezed light!

1. Turn off the amplifier and make sure that the nonlinear arm is terminated by an optical terminator and not connected to the BS. Now, connect the output of the SHG to the OPA instead and turn the amplifier back on.
2. Measure the LO arm after the polarisation controller. Attenuate the light until you have an optical power of 5 mW. The photodiode cannot handle more than 10 mW and it is thus important to stay well below this number.
3. Start the spectrum analyser and follow the guide on how to use the spectrum analyser above. Start the oscilloscope and use the Arbitrary Waveform Generator to generate a sinusoidal wave with a peak-peak of around 6 V_{pp} and a frequency of 1 Hz. Before turning on the signal output, carefully connect the output of the oscilloscope to the FS, since the BNC connector at the FS is fragile.
4. Start by viewing the noise floor of the photodetector, when no light is coupled in to it. This is called dark noise (Task 3a).
5. Connect the LO to the BS and see how the amplitude increases. Save a trace of this measurement. We call this the shot noise (Task 3a).

6. Insert the squeezed light to the BS now and set the temperature of the OPA to 51.5° . What do you see? Can you see squeezing arches? Try to move the paddles on the polarisation controller and see if you can resolve arches with as high a peak-peak value as possible. You might also want to optimize the temperature of the OPA for better results.
7. What are the anti-squeezing/squeezing values you can get? The difference between this value and the shot noise value is your measured squeezing level in dB. The difference between the highest peak value and the shot noise value is your anti-squeezing level instead. To get a good measurement of this, it is recommended to do a single sweep measurement and then use the markers to find the squeezing level and the anti-squeezing level (Task 3b).
8. Show one of the screenshots of the squeezing measurement to your lab supervisor before proceeding to turn off the emission of the laser and so on.

11 Data documenting and presentation instructions

If you want, you can use this jupyter notebook to document your data - <https://colab.research.google.com/drive/15YXdwyiNlRmijFWOQck0sxxPHxRm0tY?usp=sharing>

In the presentation:

- Start with a brief introduction to squeezed light generation
- Comment on the stability of the laser used in the experiment
- Describe the SHG fit, what function did you have to use for the fit and why?
- Describe the zero span measurement - for example you can include what the settings of the spectrum analyser were, did you notice a correlation between the applied voltage and the number of arches seen, were the squeezing and antisqueezing so asymmetric? Does the experimental data qualitatively agree with the theoretical estimate? How can you achieve more squeezing with this setup?
- Highlight an experiment (with referencing the paper) where squeezed light has been used. Make sure to describe which part of the experiment benefited from the use of squeezed light