# TDR Ch4 (updates 2)

1.1 Already discussed

1.2 Already discussed

1.3 To be detailed (next week)

1.4 Problem of the threshold power

1.5 Already discussed but I could add other considerations (next week)

1.6 Completed with the final configuration and results.

## 1.4 Estimated threshold power

As Yurke first showed in 1984 [REFERENCE] to make possible the production of squeezed light by a parametric down conversion process, it needs to work in *subthreshold* regime. So, it is important to calculate the threshold power for our OPO.

The value of the threshold depends on cavity parameters and the non-linear conversion efficiency of the crystal [REFERENCE WuXiaoKimble]:

$$P_{th} = \frac{\pi^2}{4F^2 B E_{NL}} \qquad B = \frac{T_1}{(1-\sqrt{R_1 R_2})}. \tag{1.1}$$

where F is the cavity finesse at 1064 nm, B is the *buildup* parameter [1] (the ratio between the one-way circulating power into the cavity and the incident pump power, in the absence of coupling) and $E_{NL}$ is the *nonlinear conversion efficiency*[2]. In case of perfect mismatch ($\Delta k = 0$), for our cavity $E_{NL} = 0.0115W^{-1}$, $B = 2.6$ and considering that the finesse of out cavity is about $F = 75$ we can found that the predicted threshold power is 14.7 mW.

**TOO LOW!!!**
**For GEO is about 60 mW**

[2] The nonlinear conversion efficiency is defined as

$$E_{NL} = \frac{2\omega d_{eff}^2 l^2}{\pi \epsilon_0 c^3 w_0^2 n^3} sinc^2\left(\frac{\Delta k l}{2}\right)$$

where $l$ $d_{eff}$ is the *effective nonlinear coefficient* ($d_{eff} = 10.3$ pm$/V$ for KTP), $l$ the crystal length and $\Delta k$ the momentum mismatch between the pump beam and the beam at the fundamental frequency.

For SHG

$$P_{2\omega} = P_{\omega}^{2} \frac{2\omega^{2} d_{NL}^{2} l^{2}}{\pi \epsilon_0 c^3 w^2 n^3} sinc^2 \left( \frac{\Delta k l}{2} \right)$$

$$\frac{P_{2\omega}}{P_{\omega}} = E_{NL} P_{\omega}, \qquad d_{eff} = \frac{2 d_{33}}{\pi},$$

In our case

$$\frac{P_{\omega}}{P_{2\omega}} = E_{NL} P_{2\omega}$$

this experiment. The poling reduces the effective nonlinear coefficient of the crystal by a factor

$$d_{eff} = \frac{2 d_{33}}{\pi}, \tag{3.6}$$

where the $d_{33}$ coefficient is the scalar component of the nonlinear coefficient used in this experiment. For KTP, $d_{33} = 16.2$ pm/V which makes the effective coefficient $d_{eff} = 10.3$ pm/V [Sutherland, 2003].

I used this value

**Measurement of nonlinear optical coefficients by phase-matched harmonic generation**

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| | |
|---|---|
| KDP | $d_{36} = 0.38$ |
| KD*P | $d_{36} = 0.37$ |
| $LiIO_3$ | $d_{31} = -4.1$ |
| $5\%MgO:LiNbO_3$ | $d_{31} = -4.7$ |
| $BaB_2O_4$ | $d_{eff} = 1.94$<br>$\lvert d_{22}\rvert = 2.2^{(b)}$ |
| KTP | $d_{eff} = 3.2$ ← NO POLING<br>$\lvert d_{15}\rvert = 1.9^{(c)}$<br>$\lvert d_{24}\rvert = 3.5$ |

I must investigate about the correct parameters to use

## 1.6 Temperature Control

To reach the phase matching condition, as in the case of second harmonic generation, the crystal temperature must be kept constant, at a value of about 35° C. Also in this case, the desidered temperature is mantained by an active control loop, using a sensor and an actuator. In the control scheme used for the OPO, two NTC thermistors [3] and a peltier element [4] (dreven by an external DC power supply) are used.

One of the two thermistors (In-Loop) is inserted in an analog circuit (Wheatstone bridge) whose output voltage (related to the NTC resistence, and then to the measured temperature) is used for a PID control loop, running under LabView. The other thermistor (Out-of-Loop) is used to measure the temperature indipendently of the control loop. This last measurement it was

[3] *Conrad Elektronik, Type: NTC-SEMI833, Part number: 188506*

[4] RS 197-0332

performed using a high precision digital multimeter[5]. This control loop make possible to reach a temperature stability of less than a mK for the Out-of-Loop measurement and of about 2 mK with the In-Loop thermistor.

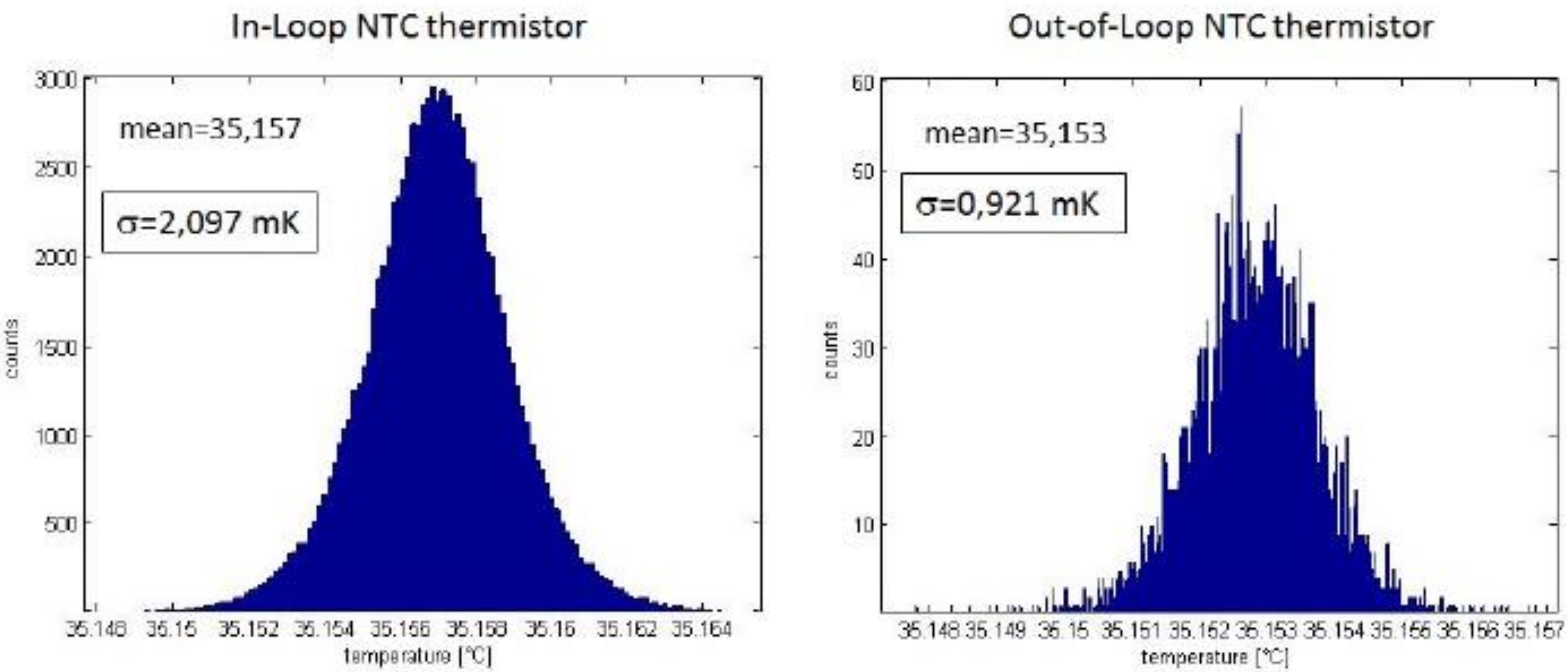


**Figure 1.7.** Measurement of the temperature stability obtained by a PID control loop.