Advanced Virgo Squeezer Technical Design Report

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Chapter 1

OPO cavity

Introduction

The OPO (Optical Parametric Oscillator) is composed by a resonant cavity with a non-linear crystal inside. The production of squeezed light is due to a parametric-down conversion process, induced by the interaction of light @532 nm (*pump beam*) with the crystal. The cavity is resonant at the frequency of the produced squeezed light (@1064 nm).

Several cavity configurations can be chosed. GEO600 and LIGO-ANU collaborations developed two different cavities for the production of squeezed light. At the AEI (Albert Einstein Institute) a 1064 nm singly resonant linear cavity was developed. While in LIGO a doubly resonant (at both 1064 and 532 nm) bow-tie cavity, developed by the Australian National University (ANU), is used. The German-British detector was the first to be enhanced by a squeezing technology. Both these configurations showed very good results [REFERENCES]; after a careful investigation, we concluded that there is no deep scientific motivation to choose a configuration rather than the other.

For Advanced Virgo we chose to reproduce a GEO-like cavity, being this consolitated for a longer time.

1.1 OPO optical design

The OPO cavity consists in a hemilitic linear resonator conceptually similar to that used for the home-made SHG [reference to Chap3].

Also in this case, a PPKTP (Periodically Poled $KTiOPO_4$) crystal was chosen; this kind of crystal make it simpler to reach the phase-matching condition so that this does not strongly depend on the crystal temperature. In addition its effective nonlinear coefficient is greater than that of other crystals (like the lithium niobate), usually used in quantum optics experiment.

Designed to resonate at 1064 nm, the linear cavity is formed by an output concave coupler mirror and one of the surfaces of the crystal, that has the appropriate RoC.

TO BE COMPLETED WITH THE FINAL WORKING PARAMETERS OF THE CAVITY

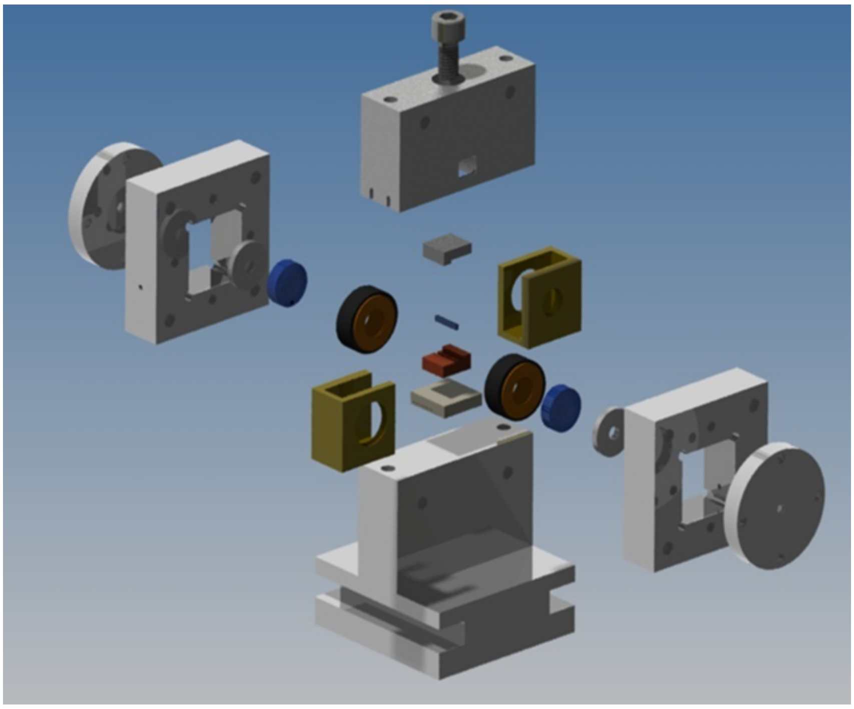

Figure 1.1. Exploded CAD drawing of the protype cavity

1.1.1 Prototype cavity

For the first tests we decided to use a symmetric linear resonator composed by two mirrors with a RoC of 25 mm with a plane and paralel faces crystal inside. This choice is mostly due to the fact that, in case of crystal damage, is less expensive to replace it.

The power reflectivity of the first mirror is $R_{1064} = 92\%$ and $R_{532} = 20\%$, for IR and green light respectevely; instead the second mirror is HR ($R > 99\%$) for both wavelenghts. To reach the stability condition a distance of 15 mm between each mirrors and the crystal was chosed.

A FINESSE simulation was used to find the cavity parameters: for the IR light the beam waist dimension is of 62 μm and the FWHM of 43 MHz; for the green light the beam waist dimension is of 44 μm and the FWHM is of 865 MHz. The risulting finesse are of 75 and 3.7 for IR and green light respectively, according to the choise to have a singly resonant cavity.

wavelength	**waist**	**FSR**	**FWHM**	**F**
1064 nm	62 μm	3 GHz	43 MHz	75
532 nm	44 μm	3 GHz	865 MHz	3.7

Table 1.1. Cavity optical parameters

1.2 Mechanical Design

The mechanical design of our cavity, as well as that of the home-made SHG, follows the design of the GEO cavity. This ensures thermal isolation, protection of the cavity from air flow perturbation and a very good mechanical stability. The OPO cavity assembly is completely dry.

In figure 1.1 we can see an exploded CAD drawing of our cavity.

The design is similar to that for the SHG, except for some material used (peek instead of macor) and for the thermistors housing. This last difference is due to the fact that, for the OPO, Negative Temperature Coefficient (NTC) thermistor will be used and they have a different shape with respect to the PTC.

As we can see in the figure, also for the OPO cavity, it was made a completely dry assembly.

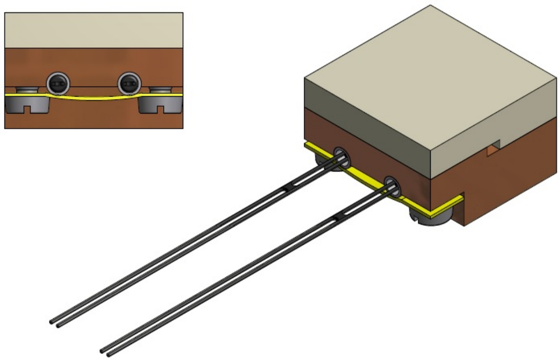

Figure 1.2. NTC thermistors dry assembly

Two grooves, with the same radius of the thermistors, are drilled in the L shaped copper plate. The two NTC thermistors enter in each of these grooves, they were fixed by a copper spring and two little screws.

1.3 Alignment and cavity length control

To align the outcoupling mirror of the cavity a *bright alignement beam* is used. This beam must have the same polarization (s-polarization) of the produced squeezed light exiting the cavity and have to be injected through the HR face of the hemilithic cavity. Careful attention must be paid to the spatial overlap between the squeezing cavity eigenmode and the green light, mostly to avoid the interaction of the pump with the higher mode of the infrared light, in order not to have squeezing level degradation.

For the OPO cavity length control, like for the other cavities (SHG and MCs), the Pound Drever Hall technique was used. The beam used for this purpose is provided by an auxiliary infrared laser and has an orthogonal polarization with respect to that of the squeezed light, so that, when this beam is trasmetted by the cavity, it can be separated by the squeezed light by a polarizing beam splitter and detected by a photodiode.

1.4 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 [1] and a peltier element (dreven by an external DC power supply) [2] are used. The control loop is currentely running under LabView.

DESCRIBE THE FINAL SET-UP FOR THE TEMPERATURE CONTROL

[1] *Conrad Elektronik, Type: NTC-SEMI833, Part number: 188506*
[2] BRAND AND MODEL