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Advanced Virgo Length Sensing and Control: Parameters for Non-Degenerate Recycling Cavities

VIR-080A-08

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Issue: 1
Date: October 8, 2008

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1 Introduction

The goal of this document is to provide a basic set of parameters for the longitudinal sensing and control system of Advanced Virgo in the option of non-degenerate recycling cavities (NDRC). The design of such cavities is briefly outlined in [1]. This note is based on considerations similar to those described for the marginally stable recycling cavities case in previous documents, see [2] and [3]. Refer to these references for details of the simulation process.

2 Modulations and lengths

2.1 Basic modulation frequency

In [1] the proposed length of the power recycling cavity is 25 m. This length determines the PRC free spectral range and consequentely the sets of allowed modulation frequencies. The free spectral range of a 25 m long PRC is about 5.996 MHz. Since this frequency must also be a multiple of the IMC free spectral range, this value sets a requirement on the IMC length. Unfortunately the required length would be of about 150 m which is too far from the present value. To maintain a IMC cavity length close to 144 m, which is similar to the Virgo value, the PRC must be made 24 m long, that is roughly doubled with respect to Virgo and to the marginally stable case.

With a 24 m long PRC, the lowest allowed frequency for sidebands is 3.12 MHz and the free spectral range of the PRC is 6.24 MHz. The basic modulation must be chosen to be close to the arm cavity anti-resonance: as in [2], the basic frequency is chosen to have a 50 Hz detuning from the cavity anti-resonance, to enforce a sufficient offset from resonance of the second harmonic.

There are two possibilities for the first modulation frequency f_1: 3.12 MHz or 9.37 MHz. The second one has been selected and the corresponding IMC and PRC lengths have been computed. These numbers are summarized in table 1. To enforce a small trasmission to the signal recycling cavity of SB1, a small Schnupp asymmetry of about 3 cm is needed.

The third modulation frequency must be chosen to be small enough and not resonant inside the recycling cavity. The choice made here is to use:

$$f_3 = 2 * FSR_{PRC} + 2 * FSR_{IMC}$$

2.2 Second modulation frequency

The second modulation must be resonant simultaneously in PRC and SRC. This requirement sets a constraint on the possible lengths of the signal recycling cavity, depending on the choice of the frequency. Some allowed

Parameter	**Symbol**	**Value**
Input mode cleaner length	l_{IMC}	144.00 m
Power recycling cavity length	l_{PRC}	24.001 m
Schnupp asymmetry	Δ	0.030 m
First modulation frequency	f_1	9368110.74 Hz
Third modulation frequency	f_3	8327209.55 Hz

Table 1: Basic lengths and modulation frequencies for the NDRC option.

Modulation frequency [Hz]	**SRC length [m]**	
28104332.23	21.334	26.667
34349739.39	21.819	26.182
40595146.56	22.154	25.847
46840553.72	22.400	25.601
53085960.88	22.589	25.412
59331368.05	22.737	25.264
65576775.21	22.858	25.143
71822182.37	22.957	25.044
78067589.54	23.040	24.961
84312996.70	23.112	24.889
90558403.86	23.173	24.828

Table 2: Possible combinations of second modulation frequency and SRC length.

values are listed in table 2. There are clearly multiple possible values for the length. In the table only the values closest to 25 m have been considered.

For each choice of frequency, the Schnupp asymmetry can be optimized to maximize the amplitude of SB2 inside SRC. The largest the frequency, the smaller the optimal asymmetry. Some combinations are listed in table 3.

3 Length Sensing and Control simulation

A full simulation of the length sensing and control system for the non-degenerate recycling cavities option has been set up using Optickle to compute the optical matrix and python scripts to simulate the loop effects, as explained in [2], for both the single and double demodulation scheme [3]. The second modulation have been chosen to be 65.6 MHz, the corresponding SRC length of 25.143 m have been selected and the optimal Schnupp asymmetry of 0.031 m used.

The error signals and control filters are the same used for the marginally stable cavities configurations, see [2, 3]. The interesting results are the performances in terms of re-injection of quantum noise, see fig. 1.

These performances are comparable with those that can be obtained with the marginally stable configuration. In the double demodulation case the noise contribution from MICH and PRCL are slightly better in the NDRC case.

4 Conclusion

A set of working parameters for the length sensing and control system in the case of non-degenerate recycling cavities have been obtained. It has been shown that the quantum-noise-limited performances of the control system is similar to the one developed for the marginally stable recycling cavity case.

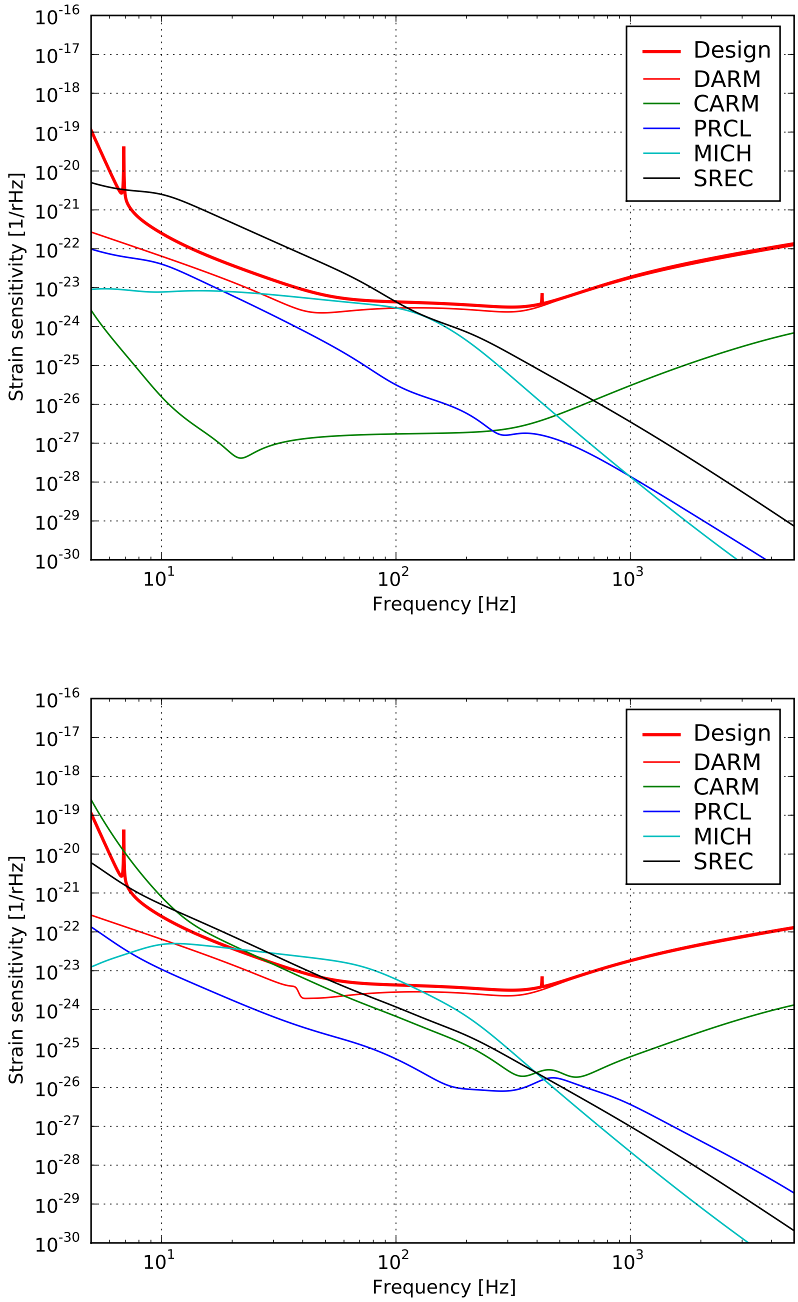

Figure 1: Noise re-introduced in the gravitational channel by the length sensing and control system, in the double (top) and single (bottom) demodulation schemes.

Modulation frequency [Hz]	**SRC length [m]**	**Optimal Schnupp [m]**
46840553.72	25.601	0.044
53085960.88	25.412	0.039
59331368.05	25.264	0.034
65576775.21	25.143	0.031
71822182.37	25.044	0.029
78067589.54	24.961	0.026

Table 3: Possible combinations of second modulation frequency and SRC length.

References

[1] A. Freise, *"A possible design for a non-degenerate power recycling cavity for AdV"*, talk at the Advanced Virgo Bi-weekly meeting of September 11th 2008. 1

[2] G. Vajente, *"Simulation of Advanced Virgo Length Sensing and Control system"*, VIR-068A-08 (2008) 1, 2

[3] G. Vajente, *"Advanced Virgo Length Sensing and Control: Double demodulation vs Single demodulation"*, VIR-069A-08 (2008) 1, 2