Variable reflectivity signal-recycling mirror and control

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Outline

- Tuned and detuned signal recycling
- Introduction of VRSM
- Layout of the initial experiment
- Error signals
- First results
- Carrier/Subcarrier offset phase-locking control scheme
- Summary

Signal Recycling I

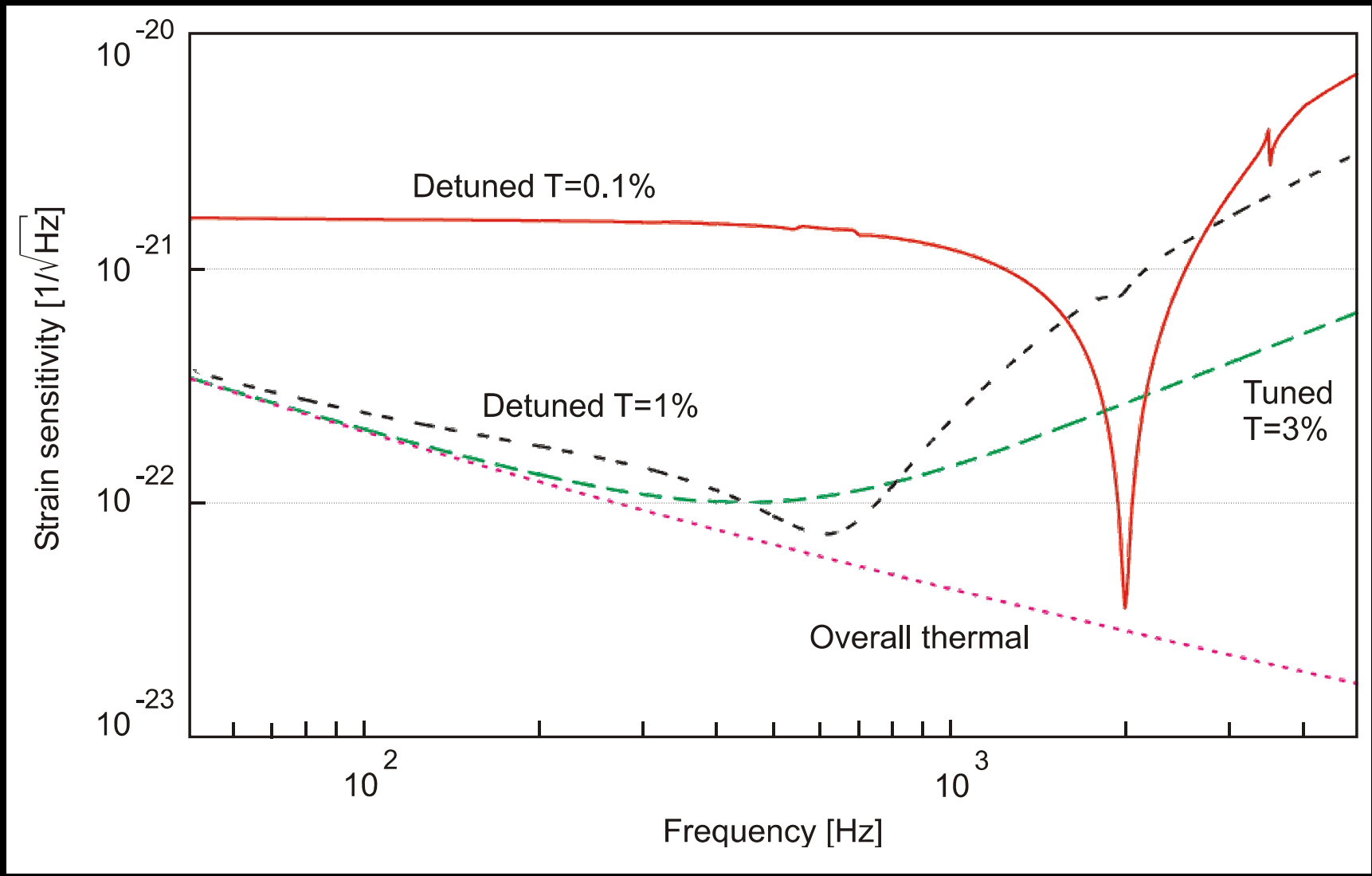
Signal recycling can be used to enhance SNL sensitivity of gravitational wave detectors within certain bandwidth:

- **Tuned** SR: SRC is tuned on resonance with carrier
  Requires broadband mode: **low finesse** of SRC
- **Detuned** SR: SRC is detuned from resonance with carrier
  Enables narrowband mode: **high finesse** of SRC

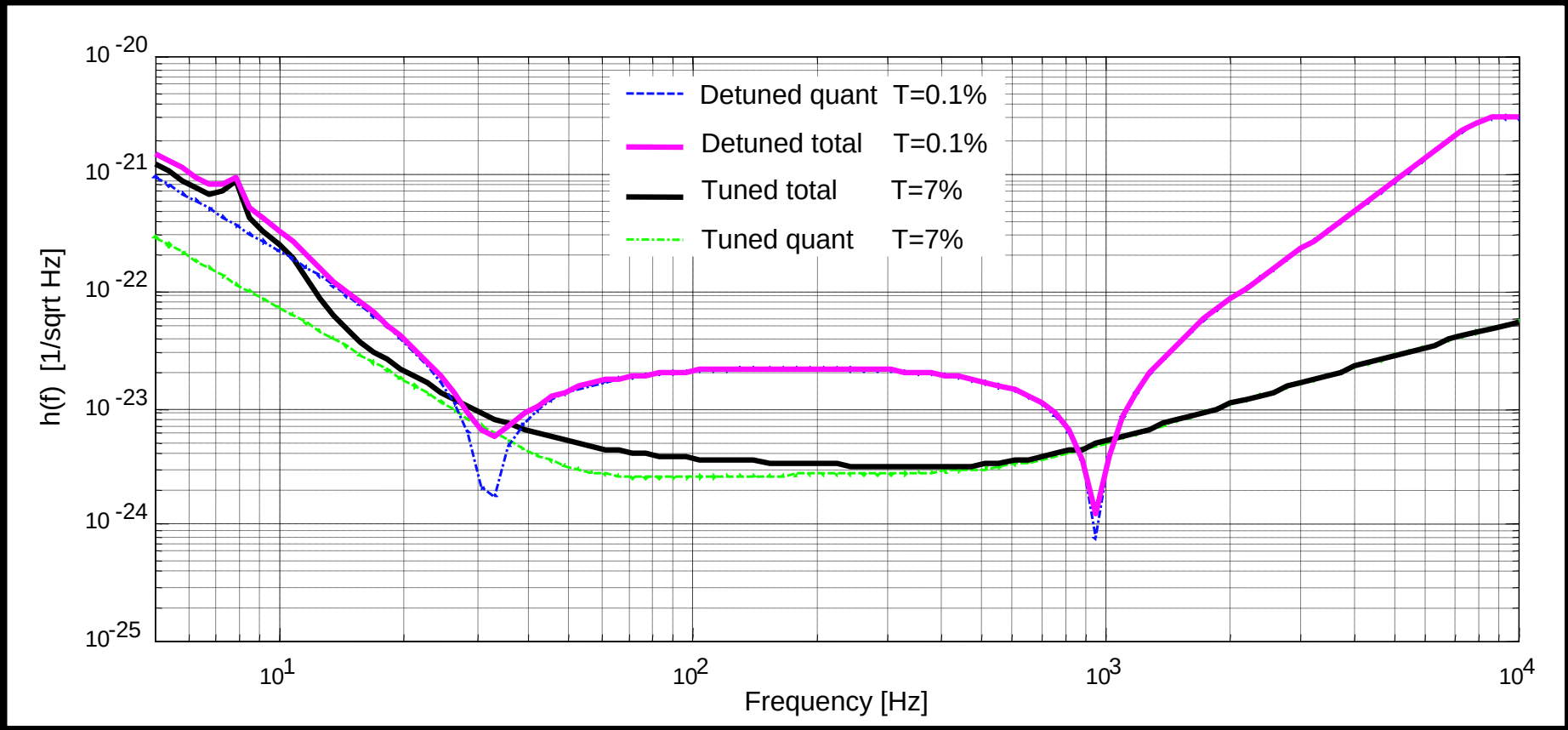
Microscopic tuning of SRM **position** alters the **tuning**

Changing the **reflectivity** of SRM alters the **bandwidth**

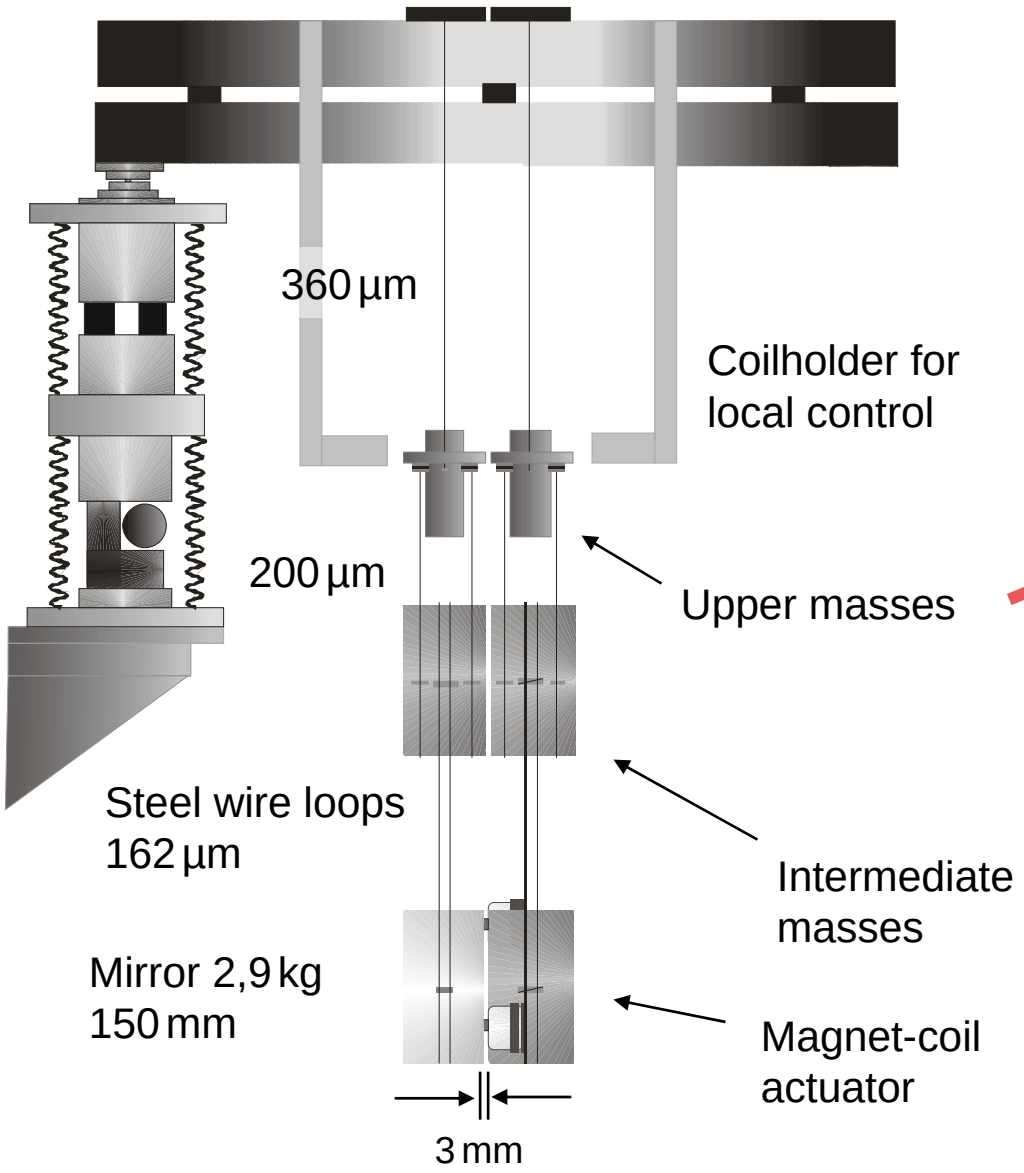
Signal Recycling II

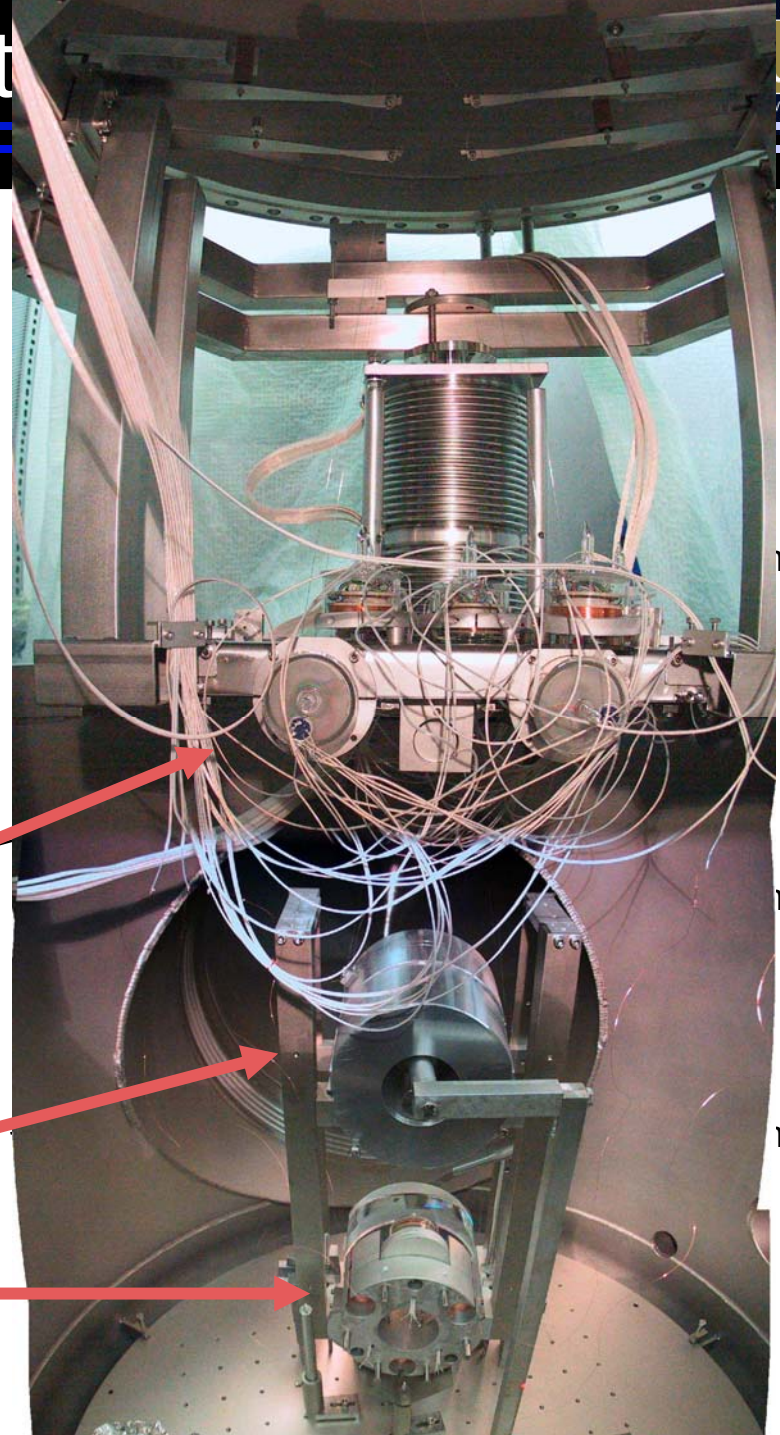


125W input


Detuned quant T=0.1%
Detuned total T=0.1%
Tuned total T=7%
Tuned quant T=7%
h(f) [1/sqrt Hz]
Frequency [Hz]
10 -20
10 -21
10 -22
10 -23
10 -24
10-25
10^1
10^2
10^3
10^4

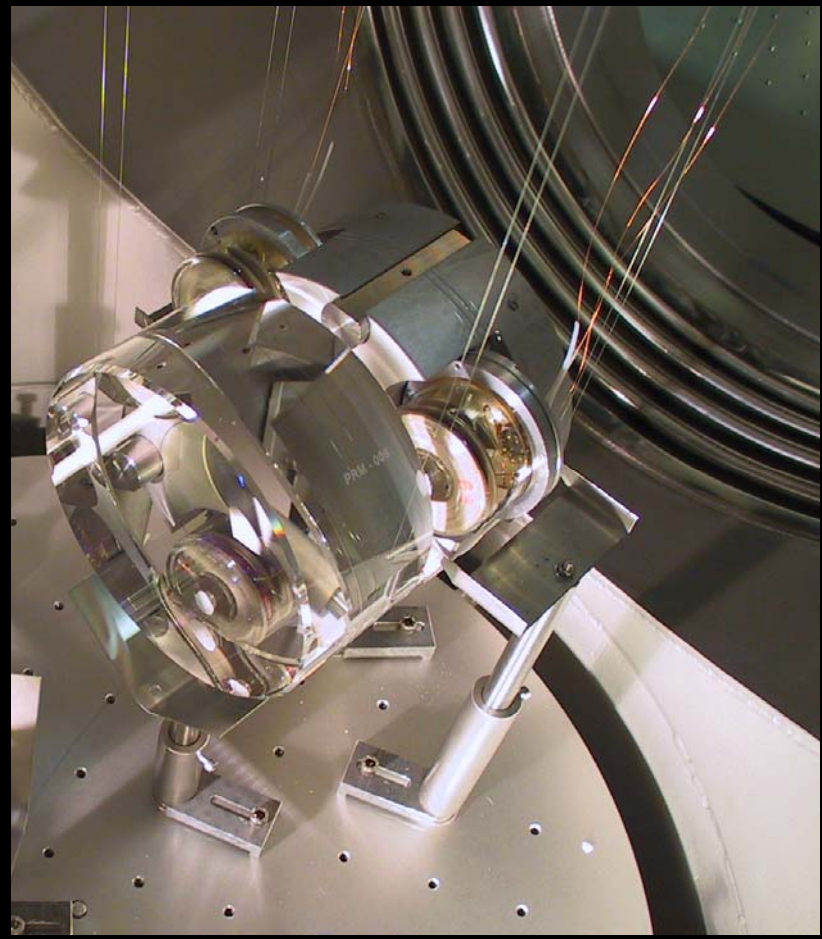
Complicat


Rotational stage
360 µm
Coilholder for
local control
200 µm
Upper masses
Steel wire loops
162 µm
Intermediate
masses
Mirror 2,9 kg
150 mm
Magnet-coil
actuator
3 mm



Complicaton:

Changing the reflectivity of the signal-recycling mirror causes a down-time of the GWD for a substantial period of time!



Solution:

A mirror with a reflectivity that can be varied on demand: a VRSM

VRSM

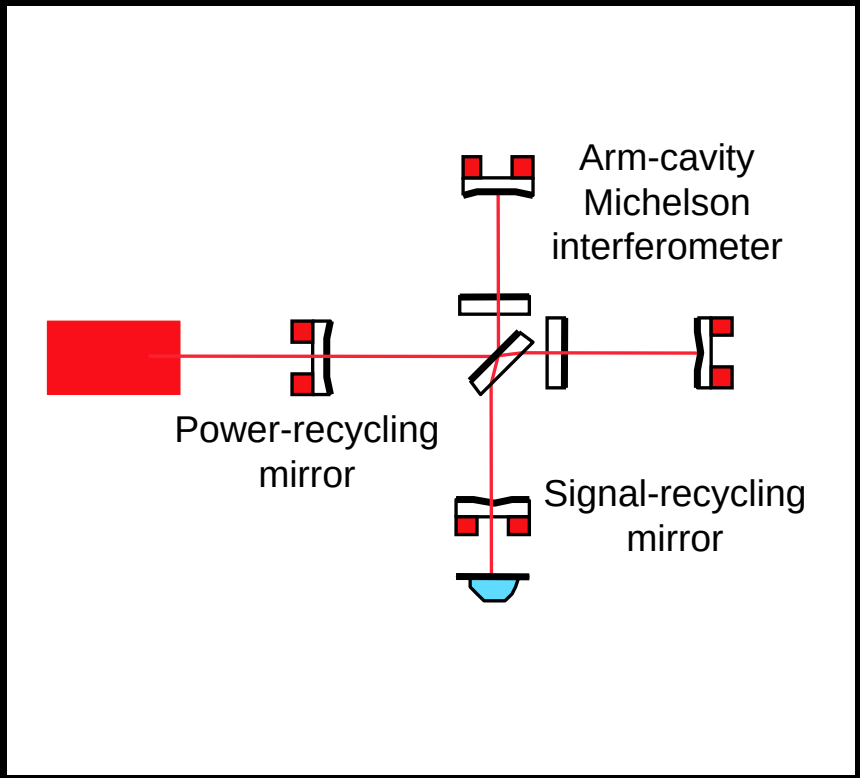
Can be realised by:

- Thermal tuning of an etalon
  Kawabe, Hild et al.
  Downside: Slow and lateral thermal gradients the substrate

- Michelson interferometer
  deVine, Shaddock, McClelland
  Downside: Very complex system

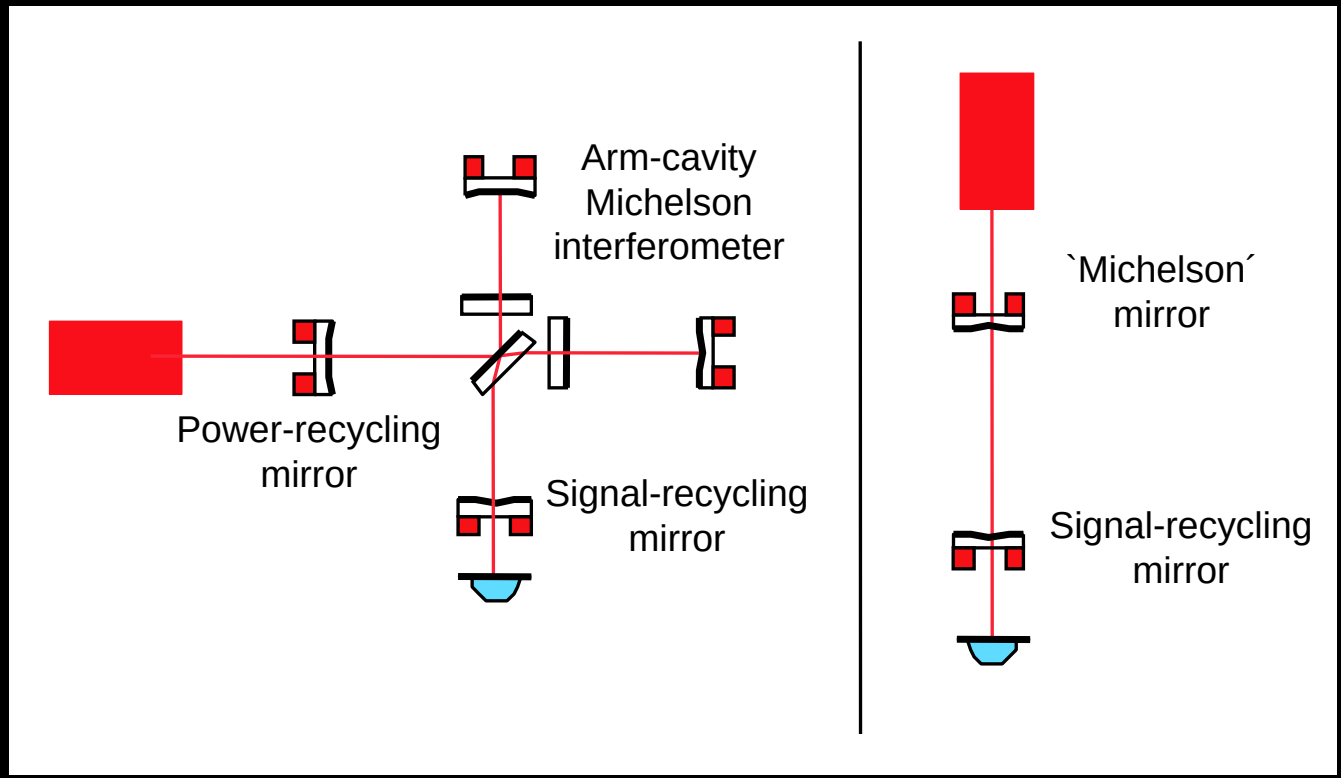
- **Fabry-Perot cavity**
  Strain, Hough
  Downside: Complex reflectivity

Simplification of Layout



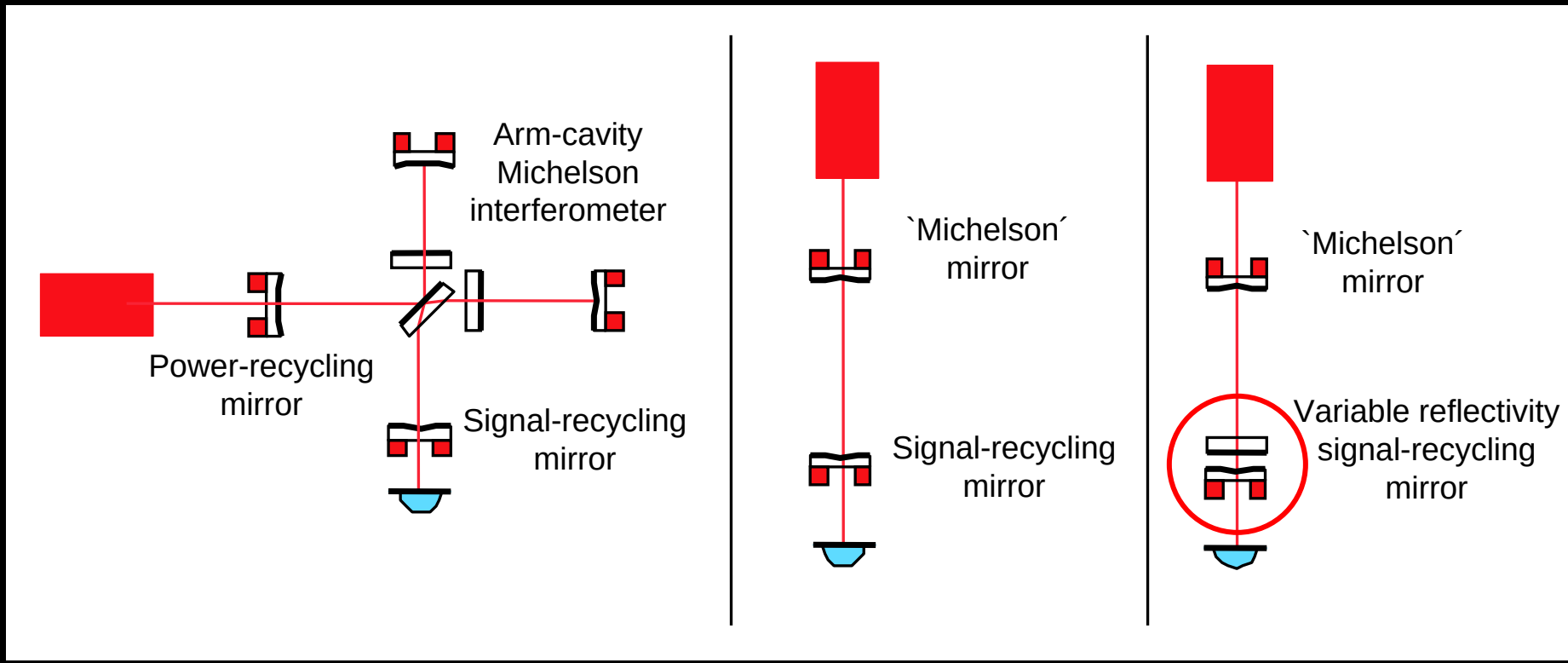
Dual recycled
Michelson interferometer
with arm cavities

Simplification of Layout

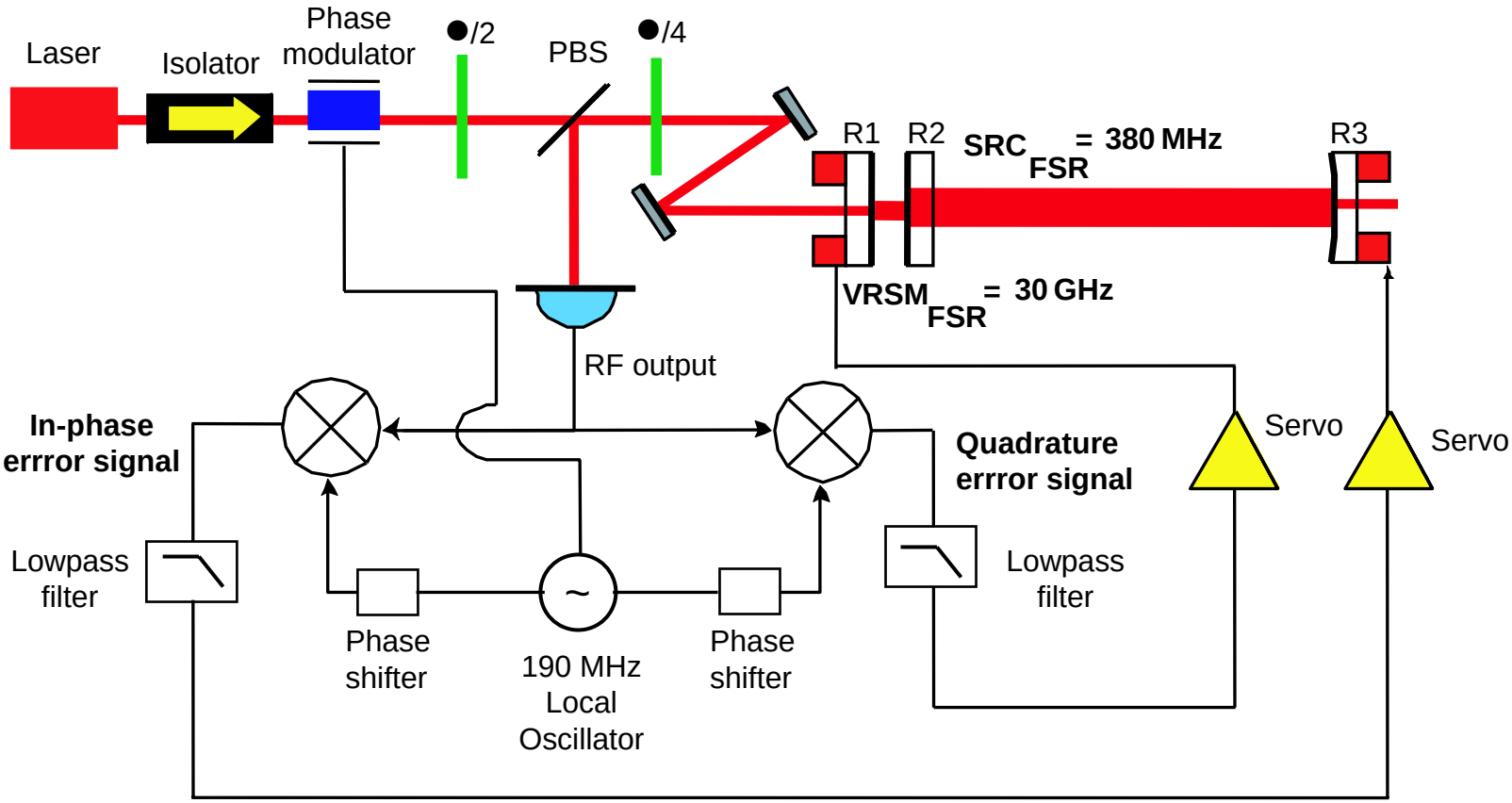


Collapse
Michelson interferometer
into one mirror

Introduction of VRSM



Experimental Layout

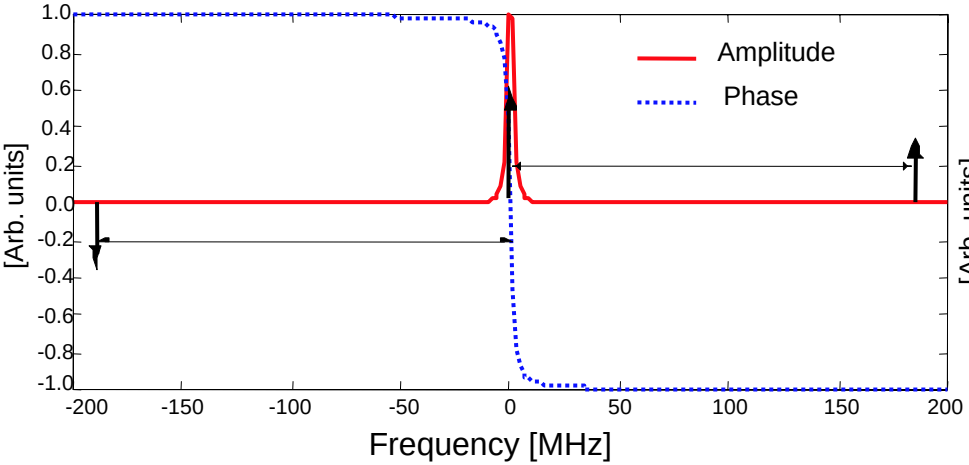


Control of SRC via in-phase error signal

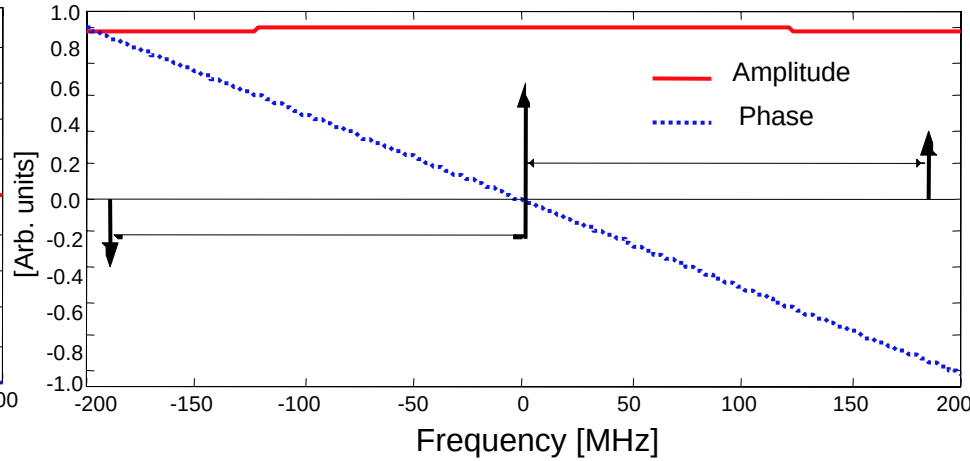
Control of VRSM via in-quardature error signal

Error Signals

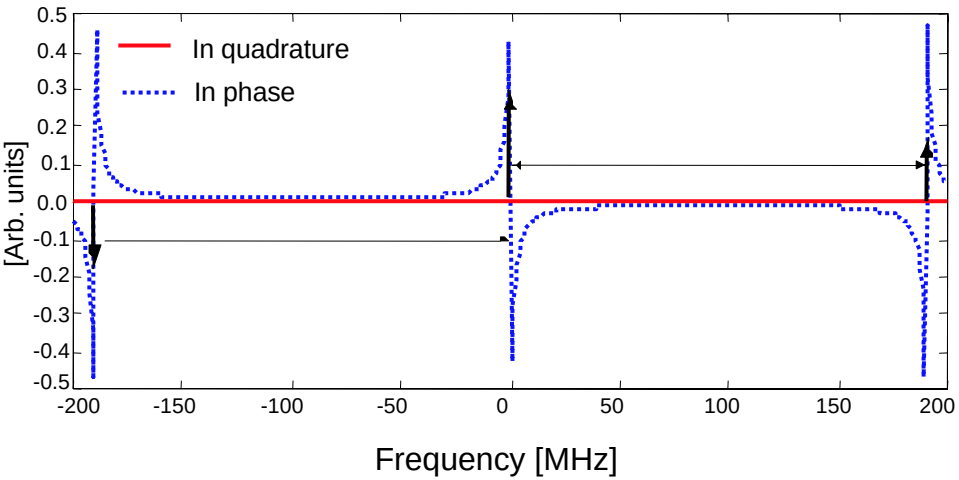
Amplitude and phase response of a narrow linewidth cavity



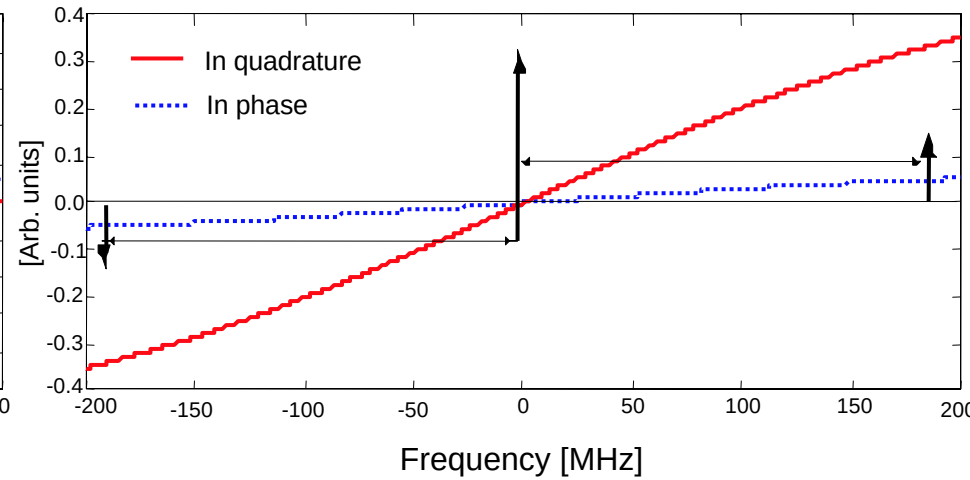
Amplitude and phase response of a broad linewidth cavity



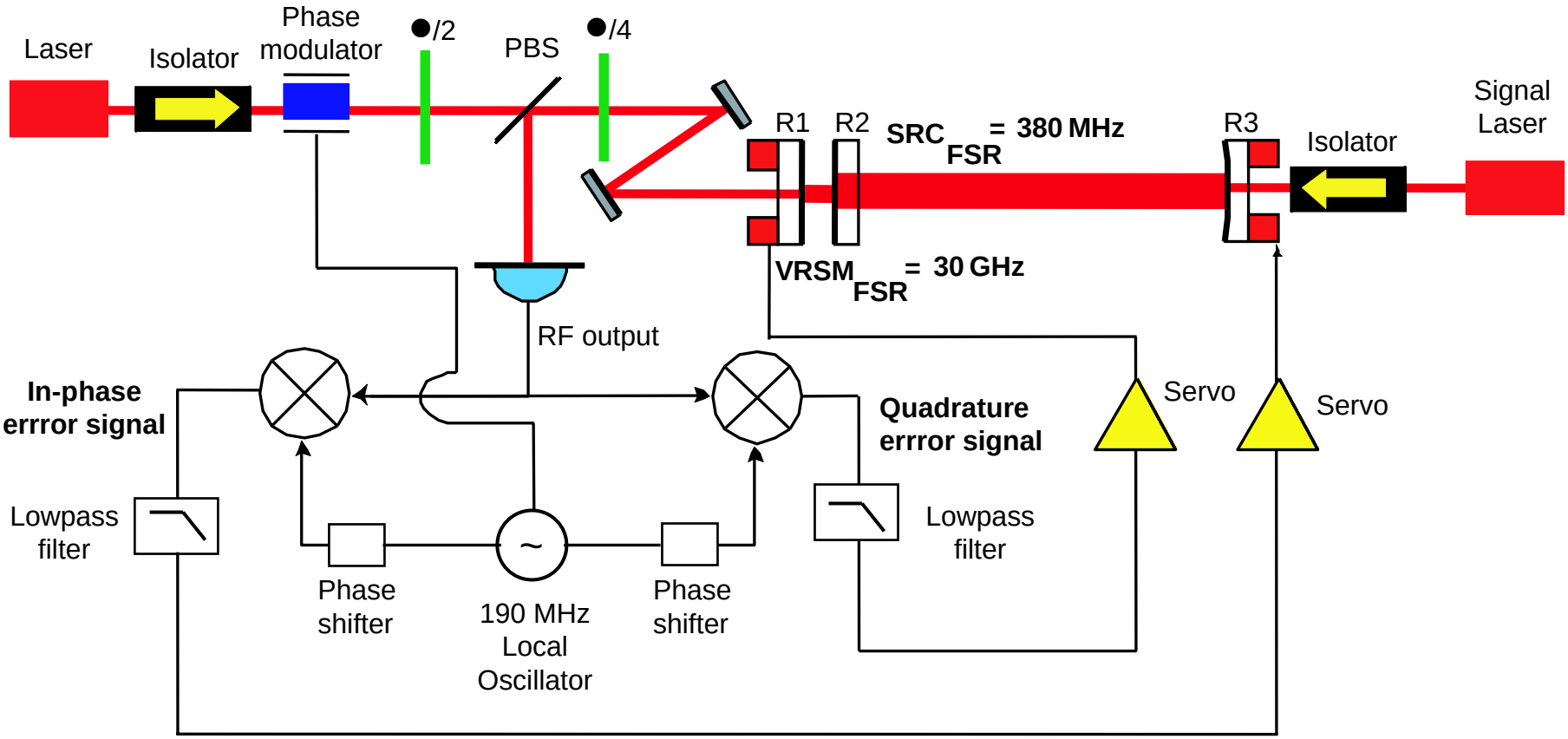
PDH error signal for a narrow linewidth cavity



PDH error signal for a broad linewidth cavity



Experimental layout



Control of SRC via in-phase error signal

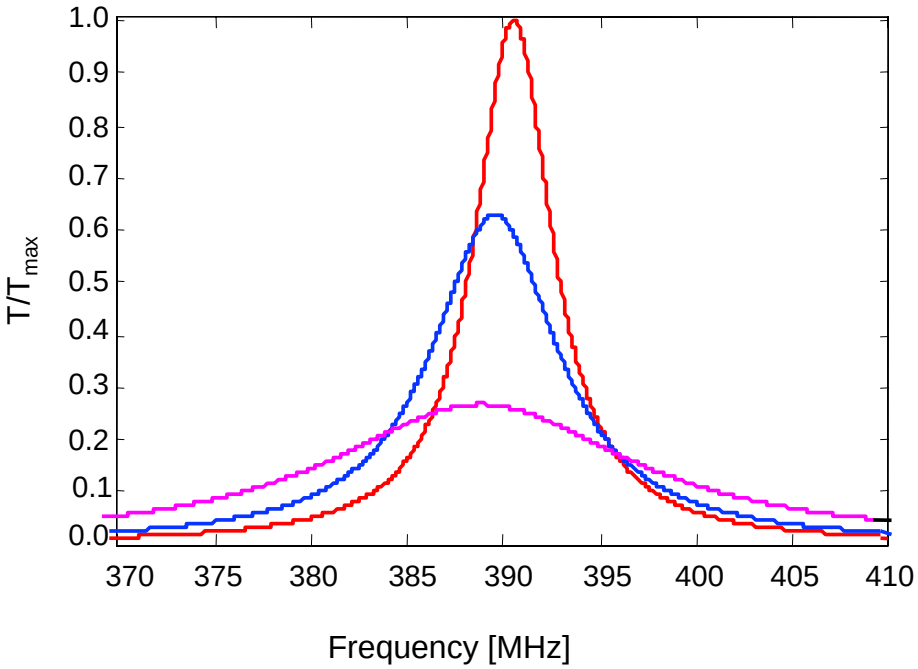
Control of VRSM via in-quardature error signal

First results...

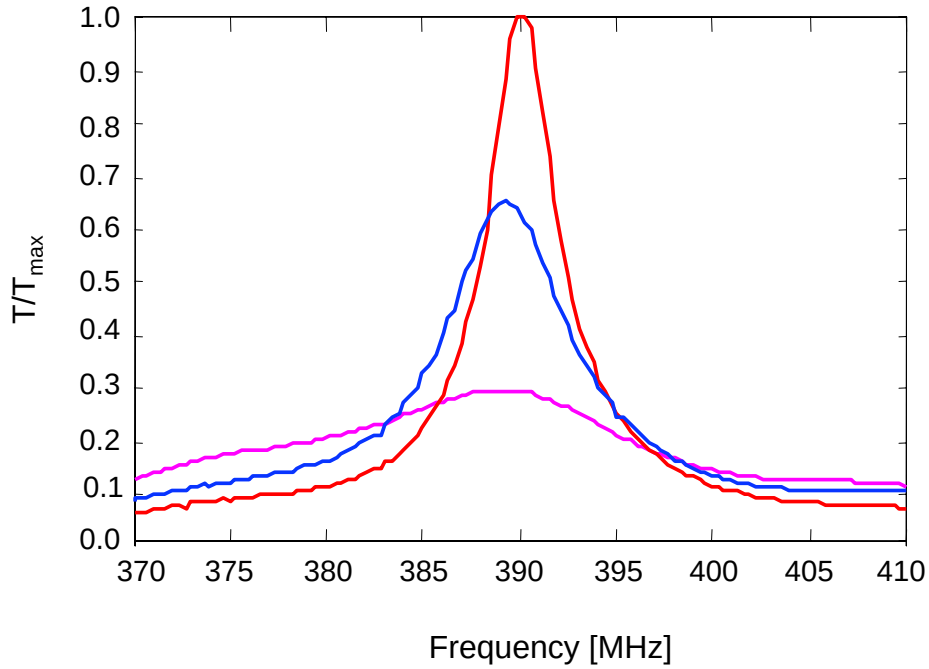
...of a linear three mirror coupled cavity when varying the reflectivity of the VRSM from

R=93% over **R=87%** to **R=63%**

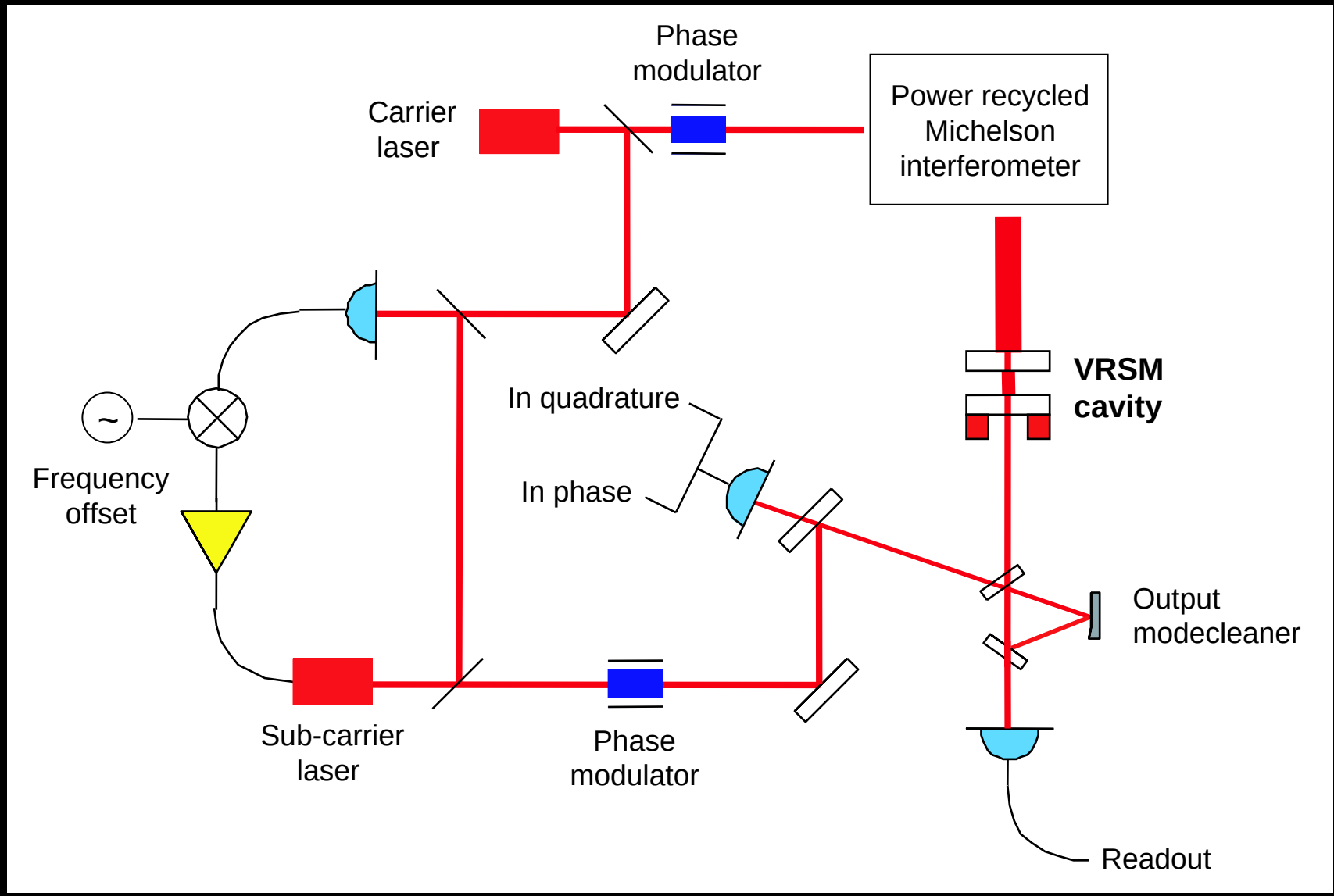
Theoretical frequency response



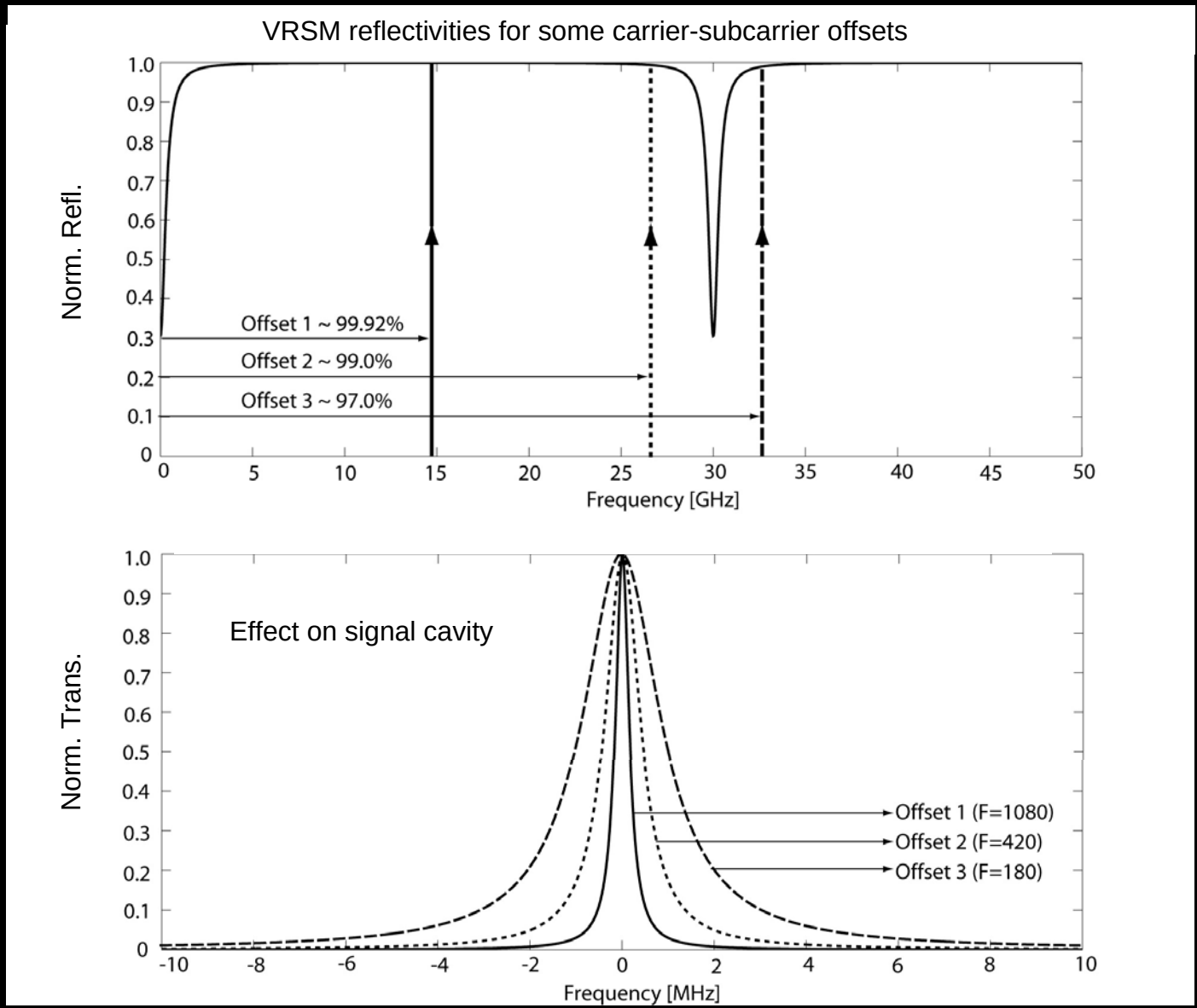
Experimental frequency response



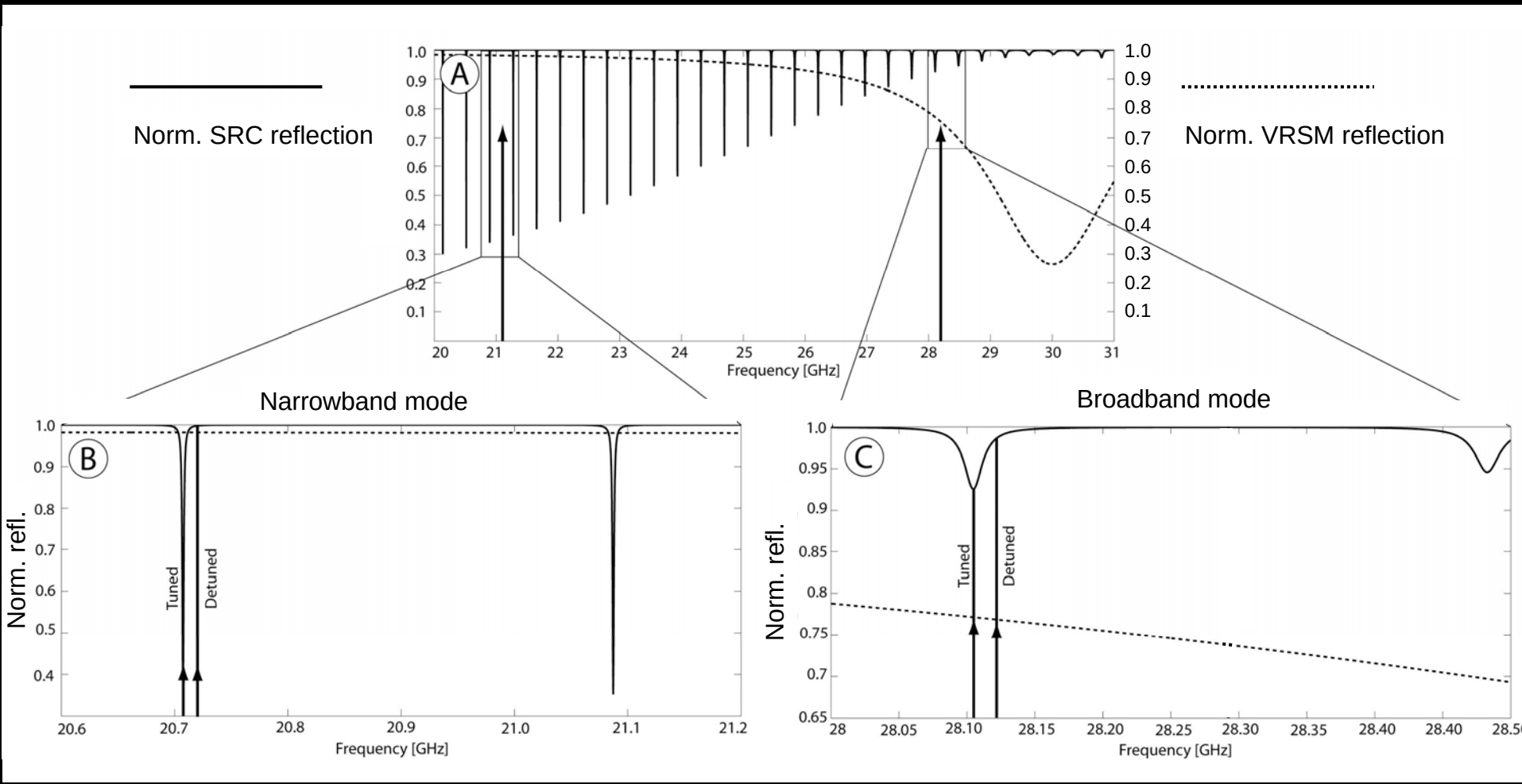
Carrier/Subcarrier



Frequency Offsets



Frequency Offsets II



Summary VRSM and Control

- The use of a VRSM eases the change of bandwidth, avoiding long down-times of the detector
- A new way to control the SRC including a VRSM by using an auxiliary laser that is offset phase locked to the carrier laser
- This control scheme is compatible with the injection of squeezed light
- First experiments using a linear three mirror cavity are carrried out
- A more complex experiment using a dual-recycled Michelson interferometer with arm cavities is in preparation