Lock Acquisition & Commissioning of the Advanced Virgo Detector

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Advanced Virgo: a 2nd Generation Gravitational Waves Detector

- **Relativistic space-time metric**

$$ds^2 = g_{\mu\nu}\, dx^\mu\, dx^\nu$$

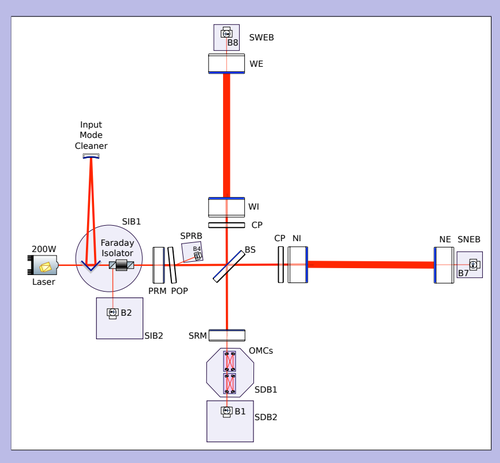
- Perturbations as **gravitational waves**

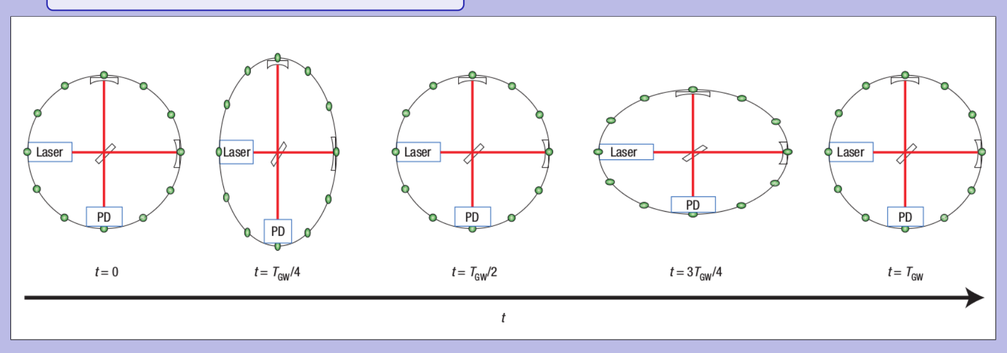
$$\left(\nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right) h_{\mu\nu} = 0$$

- Measurable quantity: the **length difference** between the arms of an interferometer
- Expected amplitude: $h \approx 10^{-21}$

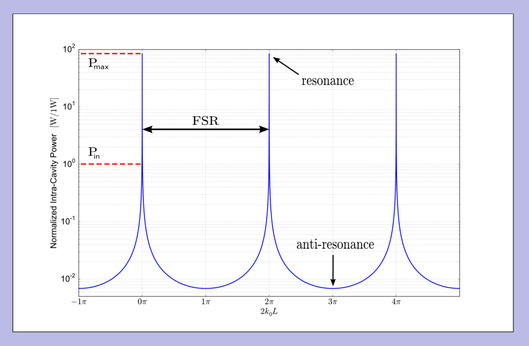
$$\Delta L \approx \frac{1}{2} hL \approx 10^{-18}\,\mathrm{m}$$

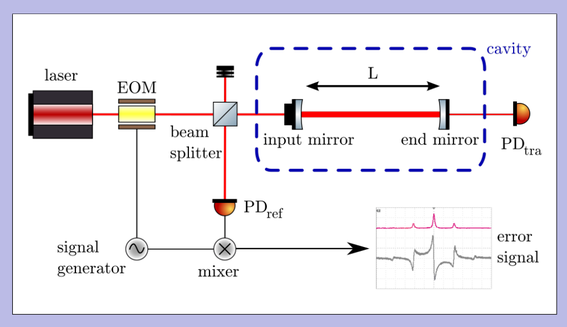
- **Advanced Virgo**'s optical layout:





Fabry-Pérot Resonant Cavities & Pound-Drever-Hall Locking Scheme





- **Operating condition**: narrow resonance at each FSR
- **Effective** arm **length**:

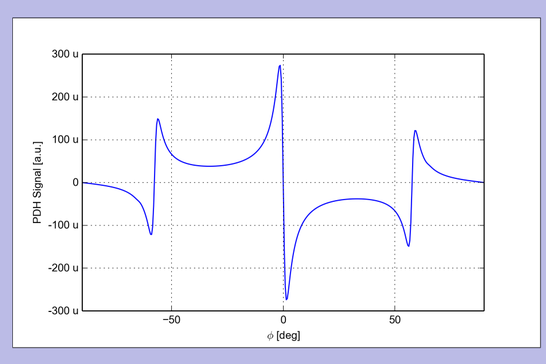
$$L' = L \cdot \frac{2\mathcal{F}}{\pi}$$

- **Finesse**:

$$\mathcal{F} \approx \frac{\pi\sqrt{r_I r_E}}{1 - r_I r_E}$$

- Electro-Optical modulation
- **Feedback control** for longitudinal and angular DOFs

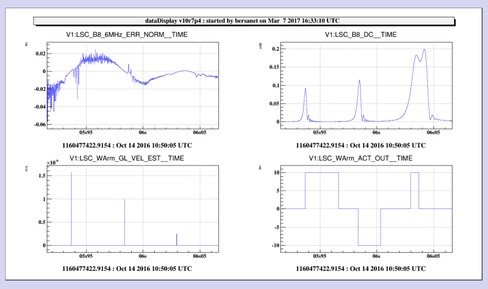
- **Metodology**: use laser's phase to keep the mirrors in position
- **Carrier** & **Sidebands** fields
- **Bipolar error signal**, **proportional to the cavity length**

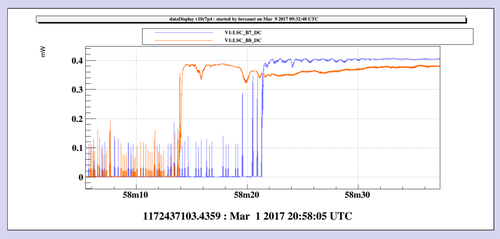


Lock Acquisition & Commissioning of the Detector

1 Lock of the Arms with the *Guided Lock* Algorithm

- **Transmitted power**'s peak is related to the **cavity velocity**
- **Calibration** with **simulations**
- **Calibrated impulses** slow down the cavities
- A linear **PDH feedback loop** is engaged to **lock the two arms**



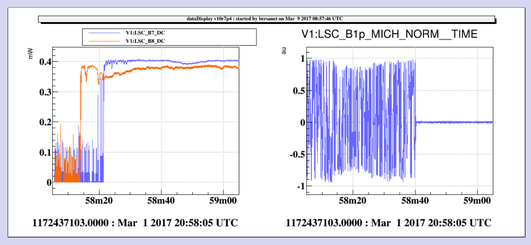


2 Lock of the Michelson with Normalized DC Power

- Use of a rescaled **DC power**

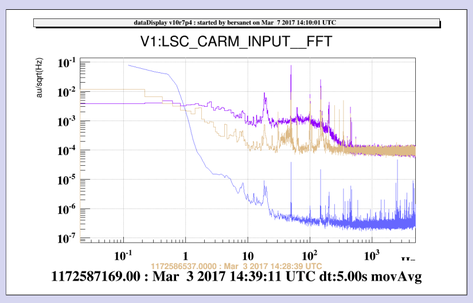
$$\mathrm{MICH} = \frac{\mathrm{B1p}}{\mathrm{B1p} + \alpha \mathrm{B4}}$$

- **Lock at Half Fringe**



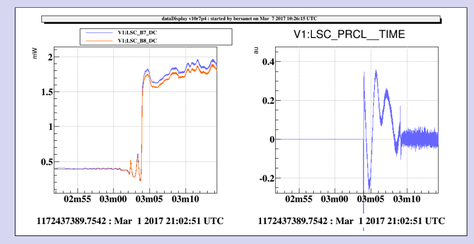
3 SSFS: Second Stage of Frequency Stabilization

- **Common arm motion** is fed back to the Input Mode Cleaner to **reduce frequency noise**
- **Improvement** of **several orders of magnitude**, already at the beginning of the Lock Acquisition



4 Lock of the Power Recycling Cavity

- **Power Recycling mirror** is then realigned and its **loop closed**
- **Light** is **recycled** in the interferometer, **increasing the sensitivity**



5 Towards Dark Fringe: *Variable Finesse* Technique

- Technique originally developed for Virgo+
- **Intra-cavity powers increase** with the Fringe offset reduction
- **Automatic Alignment** loops are engaged
- DOFs controlled with **RF error signals**
- **Reached the Dark Fringe condition**
- **Next**: ***DC Readout*** and **low-noise configuration**