Lock Acquisition & Commissioning of the Advanced Virgo Detector

Diego Bersanetti (University & INFN, Genoa (IT))
on behalf of the Commissioning Team of Advanced Virgo

XVII International Workshop on Neutrino Telescopes (Venice (IT), March 13th —17th, 2017)

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
\[ (\nabla^2 - \frac{1}{c^2} \frac{\partial^2}{\partial t^2}) h_{\mu\nu} = 0 \]

- Measurable quantity: the length difference between the arms of an interferometer

- Expected amplitude: \( h \approx 10^{-21} \)
\[ \Delta L \approx \frac{1}{2} hL \approx 10^{-18} \text{ m} \]

Advanced Virgo’s optical layout:

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

- Operating condition: narrow resonance at each FSR
- Effective arm length:
\[ L' = L \cdot \frac{2F}{\pi} \]
- Finesse:
\[ F \approx \frac{5}{1-r} \sqrt{\frac{r}{1-r}} \]
- Electro-Optical modulation
- Feedback control for longitudinal and angular DOFs

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
\[ \text{MICH} = \frac{B_{1p}}{B_{1p} + B_{3}} \]
- 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