Input Output Optics

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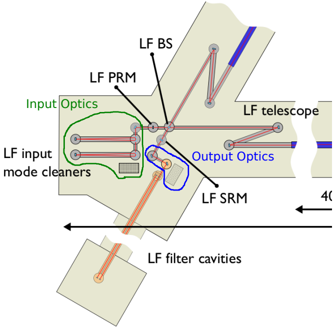
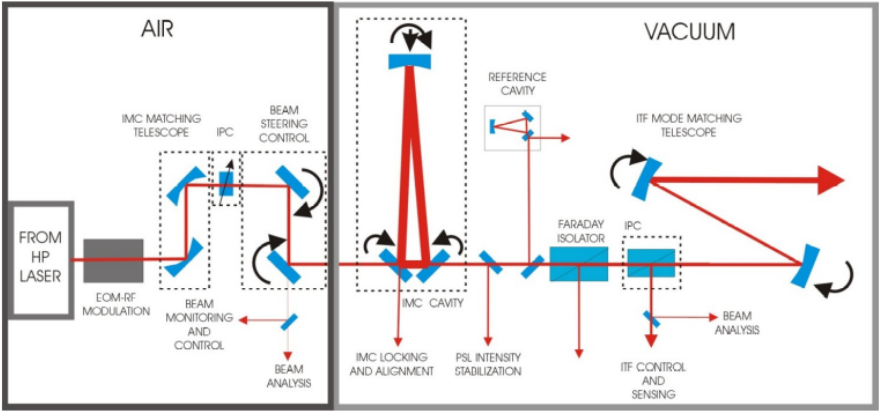
LAPP/IN2P3 - Annecy

Input Output Optics



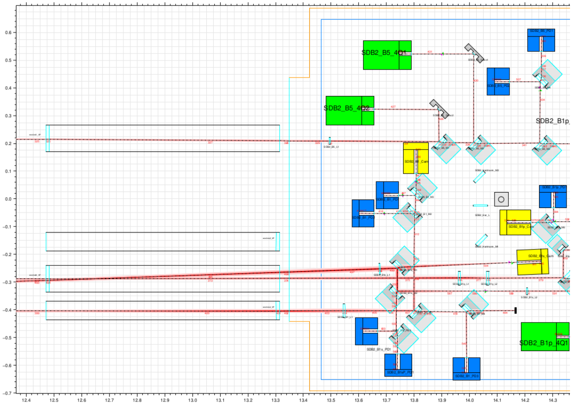
- Work Package co-chairs
  - Keiko Kokeyama, Cardiff University, UK
  - Michal Was, LAPP, Annecy, France
- Input Optics
  - Add radio-frequency sideband for control purposes
  - Transition from air to vacuum
  - Filter frequency and amplitude noise of laser
  - Take beam from laser to interferometer
- Output Optics
  - Take beam from interferometer to sensors
  - Filter higher order modes and radio frequency sidebands
  - Low losses to have effective squeezing $\lesssim 5\%$ in total
- Most optics suspended in vacuum, motion $< 1\ \mu m/s$
- Back scattered light is a critical issue

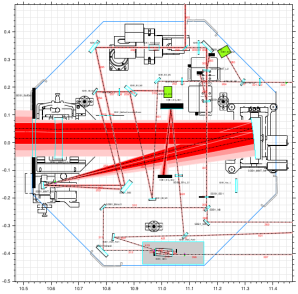
Input Optics - Advanced Virgo example



Output Optics - Advanced Virgo example

Suspended Detection Bench (SDB2)





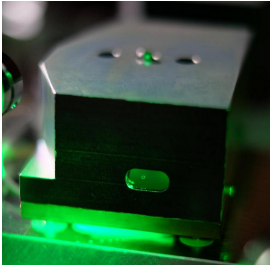
Suspended Detection Bench (SDB1)

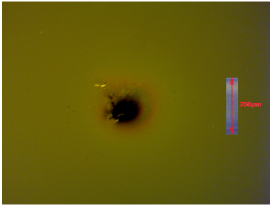
- Example of main output port, benches on 4 other output ports

Wavelength and challenges

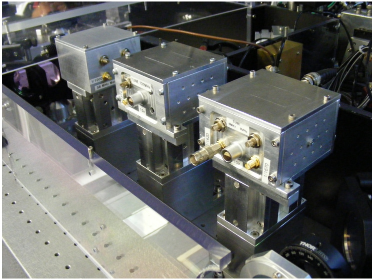
- ET high frequency - 1064 nm
  - Well known in the gravitational wave community
  - Hope improvement to known technology is sufficient
  - Challenge to deal with 700 W power (10 times more)
    - Many holes already burned in Advanced LIGO/Virgo
- ET low frequency - 1550 nm
  - Well known in the telecommunication industry
  - Hope most technology already available and affordable
  - Power is relatively small: 5 W
  - May be replaced by 1900-2100 nm if absorption is an issue

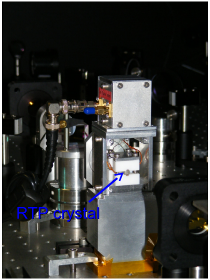
  ⇒ Many technologies would need to be developped





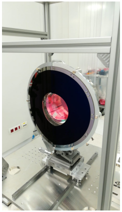
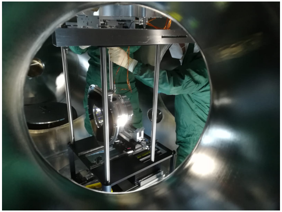
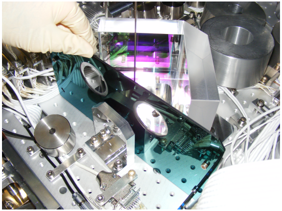
Radio Frequency sideband creation





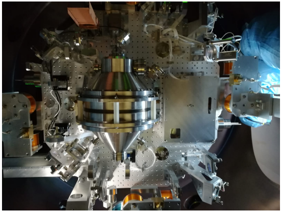
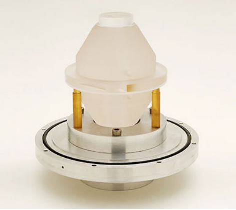
- Create 1% of light offset by 4-100 MHz compared to main laser beam
- Used for Pound Drever Hall technique of measuring optical cavities length
- Electro-optic modulator - standard solution
  - Crystal driven by radio-frequency voltage
  - High voltage ∼200 V
  - Crystal are small (5 mm) and with large absorption (0.1%)
    $\Rightarrow$ issues with high power density 700 W ?

Input Mode Cleaner

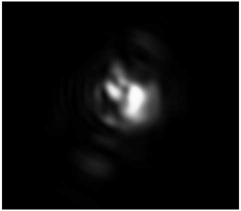
- Suspended triangular cavity, few 100 m long, finesse ∼1000
- Could be two cavities in series
- A stage in reducing laser frequency noise, amplitude noise, beam jitter
- Passive filtering above cavity pole frequency (∼ 100 Hz)
- Reference for active loops
- 300 kW circulating power?

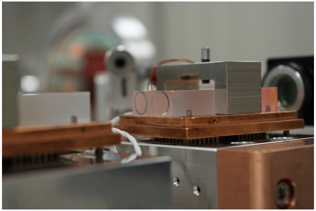
Reference cavity

- Rigid optical cavity
- Laser frequency reference at low frequency ($\lesssim 1$ Hz)
- At higher frequency 10 km arms are the reference

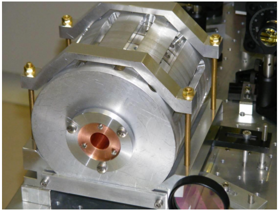
Output mode cleaner

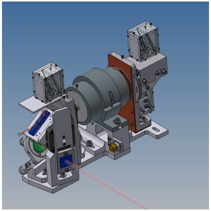




- Remove higher order modes and radio frequency sidebands
- >99% of light needs to be rejected
- Low length noise
- Two different technical solution used in Advanced LIGO/Virgo

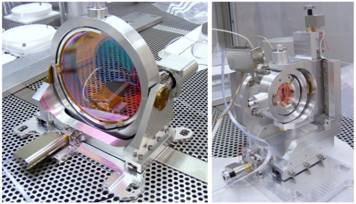
Faraday Isolator

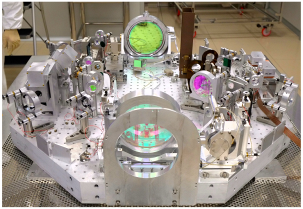




- Uses magnetic field and crystal to break time reversal symmetry
- Separate back and forward propagating beams
  - Intereferometer reflection control signals
  - Squeezed light injection
- Remove interference from back scattered/reflected light
- Crystal aperture are a few cm
- High power isolator
  700 W issues with depolarization due to absorption and thermal gradients
- Low loss isolator: $\lesssim 1\%$

Telescope

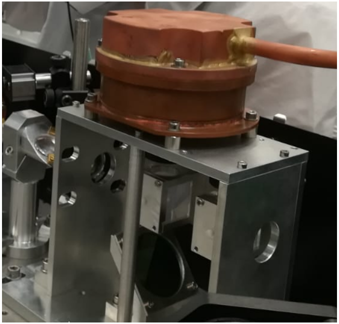


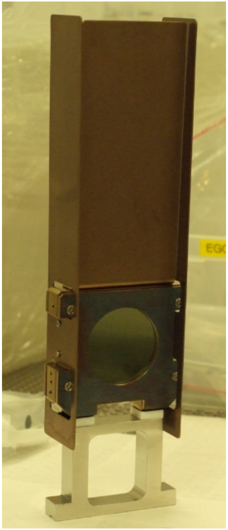


- Beam radius on crystals, sensors is $\lesssim 1\,\text{mm}$
- Beam radius in the interferometer arms is $\sim 10\,\text{cm}$
- Match several different optical cavities
  - Laser to input mode cleaner
  - Input mode cleaner to interferometer arms
  - Arms to output mode cleaner
- >99.5% mode matching needed
  - alignment
  - beam size
  - astigmatism
  - higher order defects?

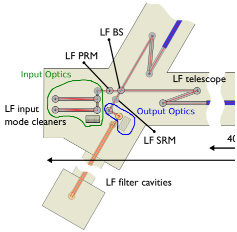
High power beam dumps / shutters

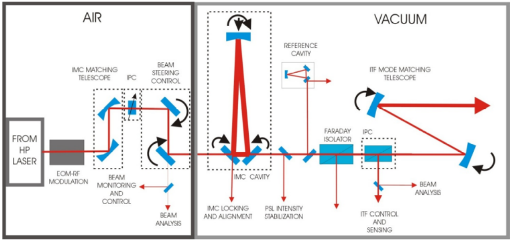
- Absorb 700 W continuous power
- Absorb 10 kW / 30 J flashes of 10 ms
- Shutter closing in 1 ms
- Low scatter/reflection
- In many cases in vacuum operation $\longrightarrow$ heat extraction
- At 1064 nm using absorbing glass, silicon, silicon carbide
- What material to use for 1550 nm?





Input Output Optics Summary





- Input Output Optics is composed of many different optical components
- In principle well known technologies in most cases
- Increase in power will be a challenge
- Reduction of losses will be a challenge
- Might get surprises at new wavelength (1550 nm, $\sim 2\mu$m)
- In practice a source of many of the technical noises in interferometers
- Each individual type of component is a manageable size project

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