Nulling Interferometer Cryogenic Experiment (NICE) – Phase 1

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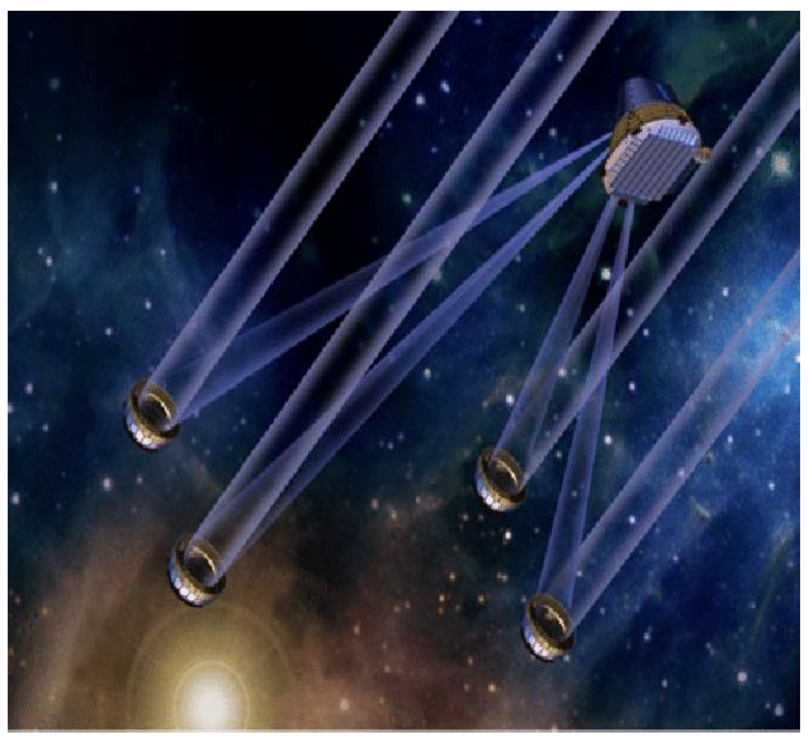
1 LIFE – Large Interferometer For Exoplanets



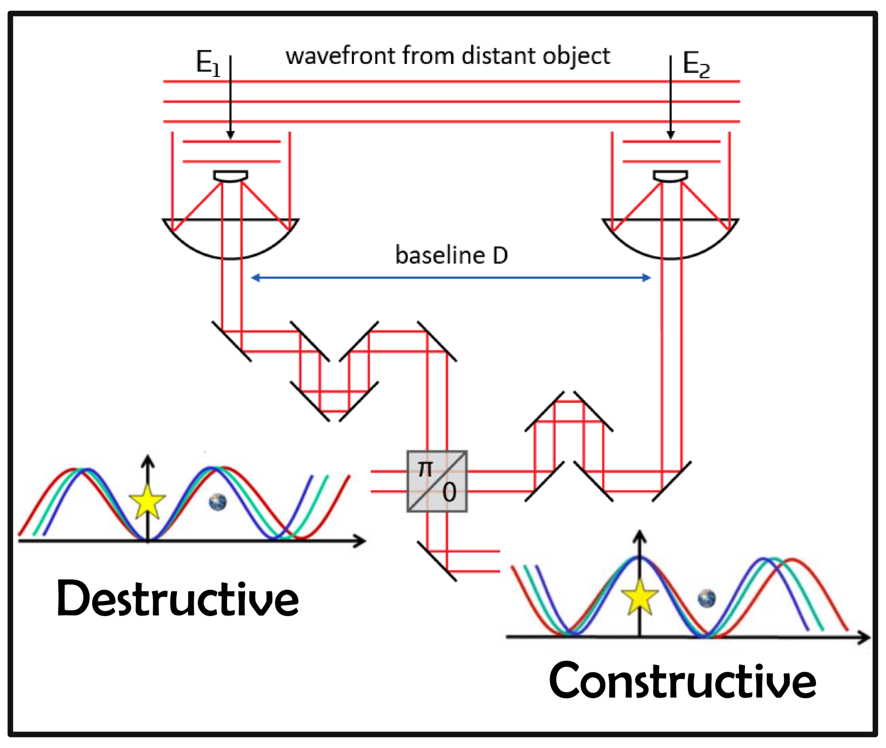
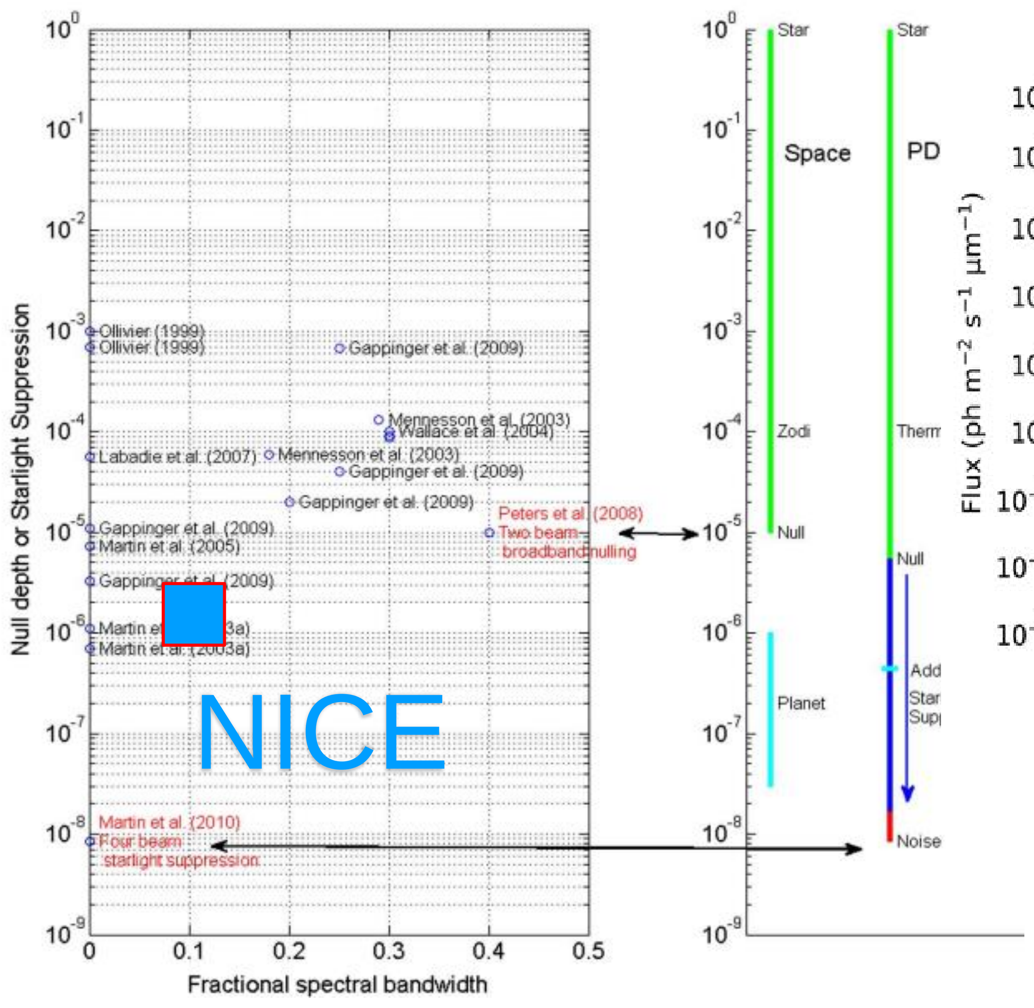


Fig 1a : LIFE is a proposed space mission to characterize the atmosphere of terrestrial exoplanets. An artistic impression of a LIFE like nulling interferometer with four collectors is shown in the figure.

Fig 1b : A schematic diagram showing the working principle of a two telescope Bracewell Nulling Interferometer. Light collected from two telescopes are combined with a *pi* phase shift. This produces a destructive interference in the 0th order. The 0th order is wavelength independent. So when the 0th order null is placed on a star, the star light is suppressed. By carefully adjusting the distance between the two telescopes, the constructive output can be placed on the planet. A typical null depth of 10^-6 is required to suppress the star light and image an Earth like exoplanet through its thermal emission.

2 Goal of NICE



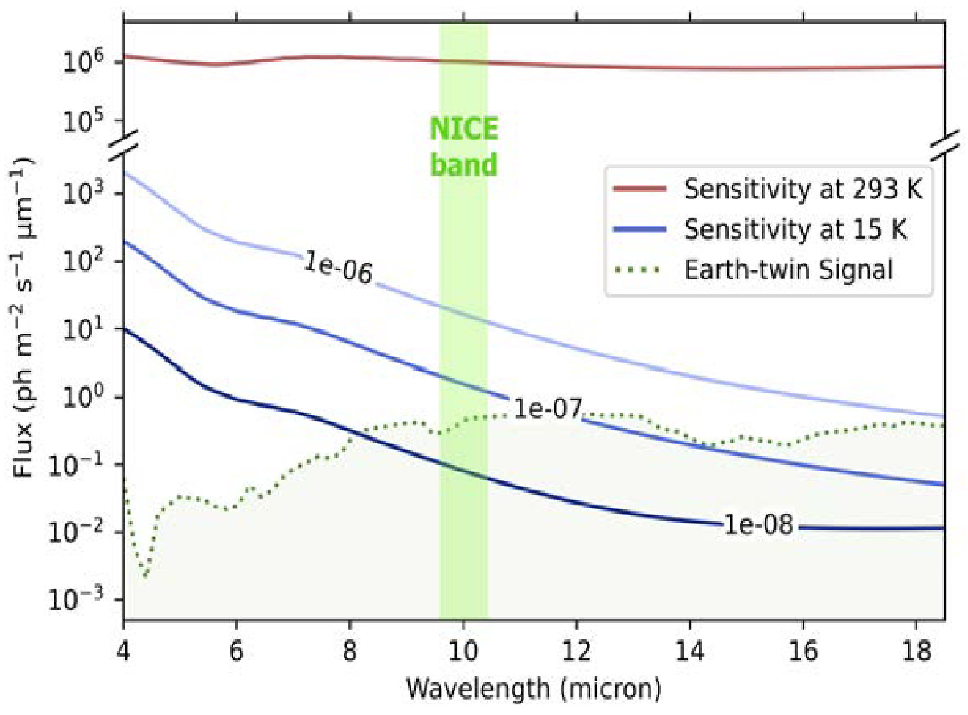


Fig 2a : This plot by *S Martin et al (2012)* summarizes the test benches that were built to demonstrate nulling interferometry using strong light sources. It shows that a null depths of 10^-8 can be achieved at monochromatic wavelength after post processing. It also shows that a null depth of 10^-5 can be achieved at 40% bandwidth.

Fig 2b : The plot shows the flux obtained from an Earth twin located at 10pc. NICE will be the first nullar that demonstrates nulling capabilities with high sensitivity. To achieve this, the instruments will be cooled to 15 K or lower. In Phase-1 of the experiment, the optical layout is built at ambient conditions.

3 Optical Functional Layout – Phase 1

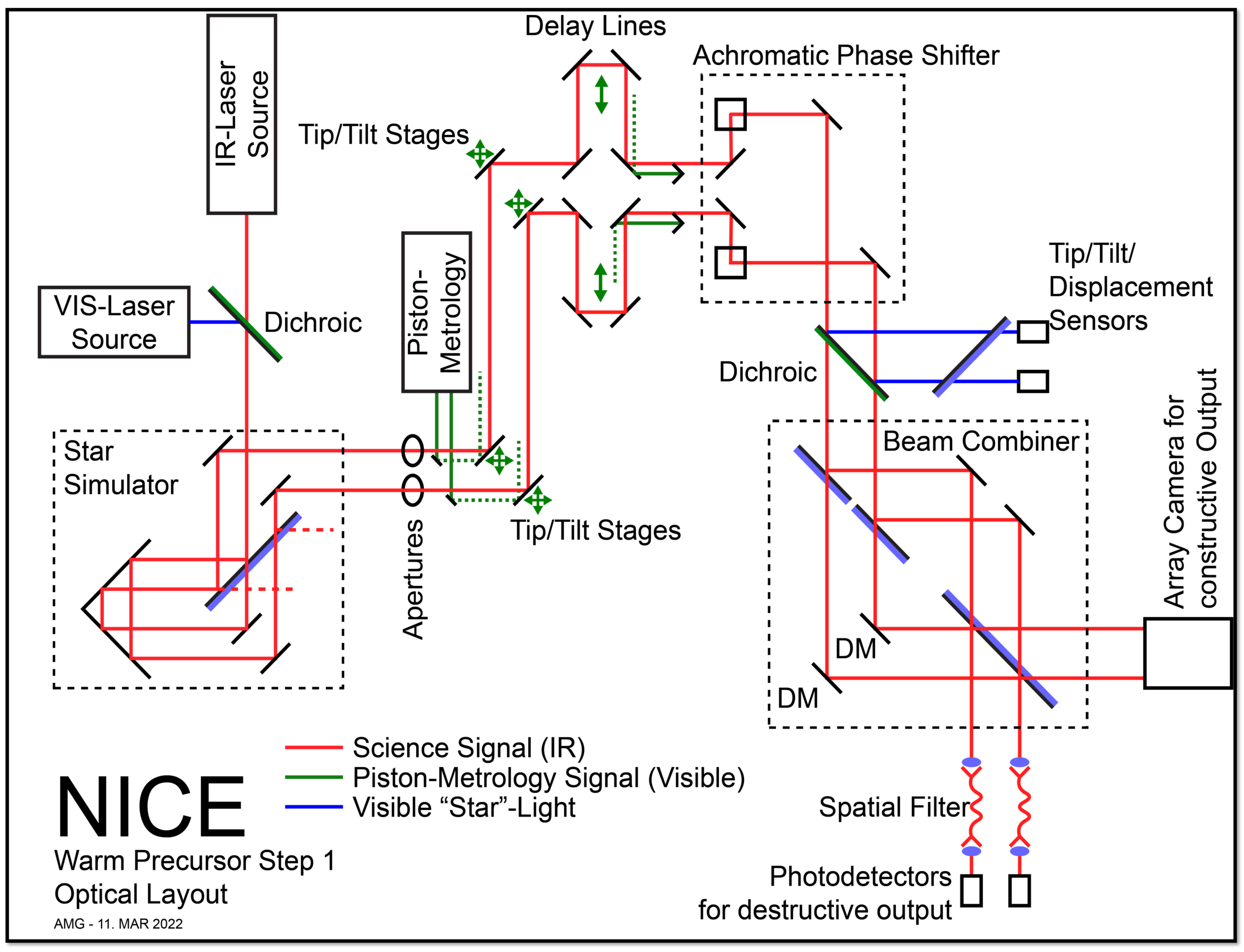


Fig 3 : This diagram shows the functional layout of NICE. The Phase-1 of NICE is built using off-the-shelf components at ambient conditions. The optical layout is divided into three segments –

- The 1st segment consists of a star simulator. The star simulator is built using a Sagnag beam divider. A single light beam is split into two identical beams. This simulates a two telescope collector.
- The 2nd segment consists of two delay lines and an achromatic phase shifter (APS). The delay lines are used to correct for the optical path difference between the two beams. The APS is a periscope system that achieves a 180 deg phase shift between the two beams using reflections from two perpendicular axis.
- The 3rd segment is a beam combiner. This is built using a modified Mach Zehnder concept. The beam combiner interferes the two incoming beams to produce constructive and destructive output. Using the delay line and APS, the destructive output can be obtained at the 0th order. The optical layout also has a metrology system that dynamically corrects for any displacement and tip-tilt errors in the system

4 Experimental setup and future upgrades (Phase – 2)

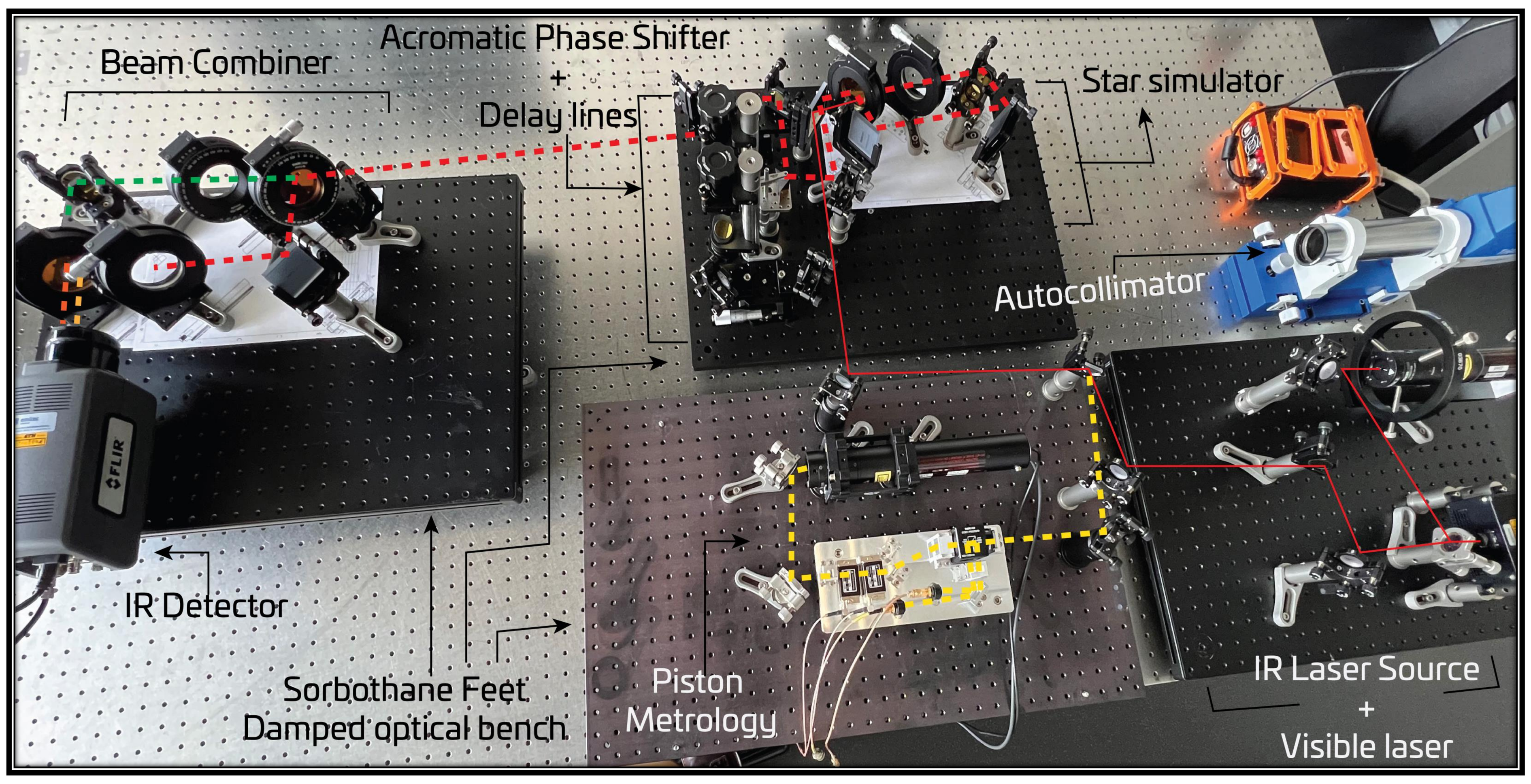


Fig 4 : The image above shows the experimental setup of NICE PHASE-1. The image also shows a partial raytrace through the setup. Currently a 3.85um IR laser is used as the source. This source will be upgraded to be polychromatic. The Phase-1 of NICE is built using off-the-shelf components in ambient condition. The drawback of this setup is long term stability. To setup will be upgraded to a monolithic design with custom mirror holders.

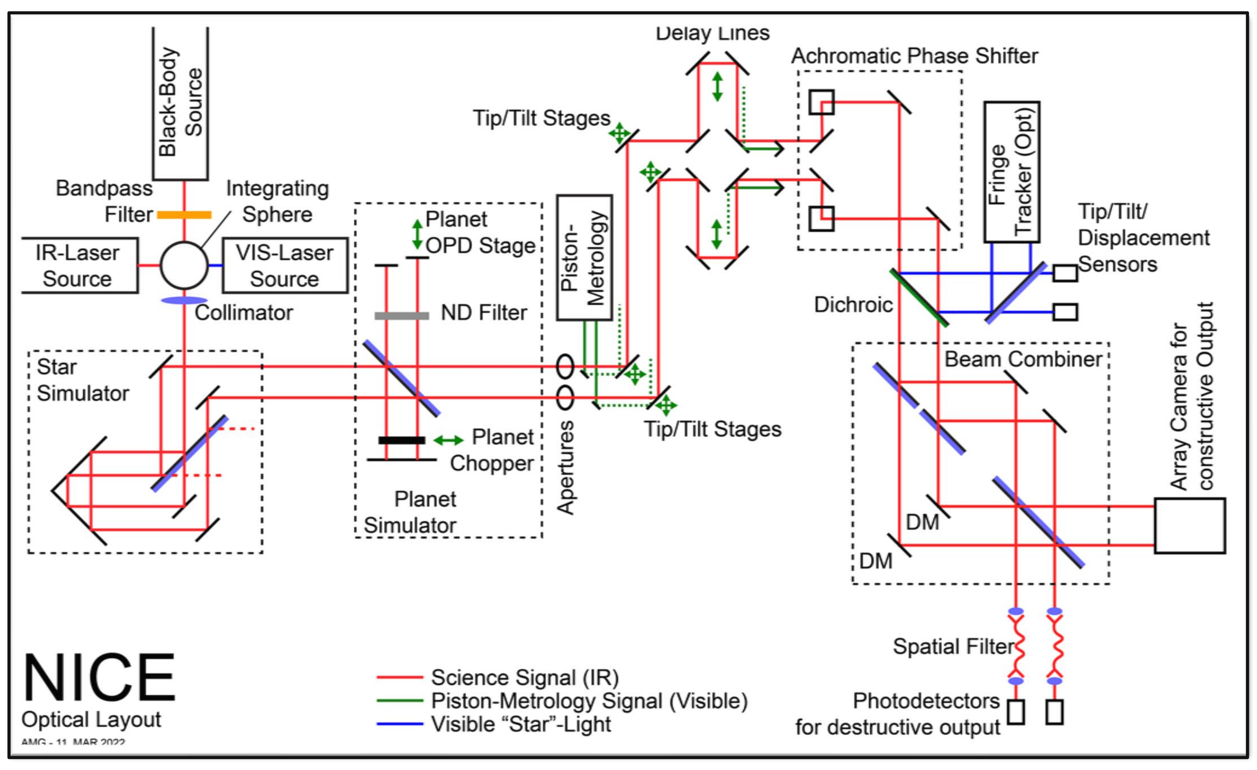


Fig 5 : The figure shows the optical functional layout of NICE in Phase-2. Here a planet simulator is included. The performance of NICE as a single Bracewell nuller will be tested for at-least a 35% bandwidth.

Upon successful tests, the experiment will go cryogenic to test the sensitivity capabilities of NICE.

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References:

[1] Quanz S. P. et al., 2021, arxiv : https://doi.org/10.48550/arXiv.2101.07500
[2] Kammerer J and Quanz S. P., 2018, A&A, 609, https://doi.org/10.1051/0004-6361/201731254