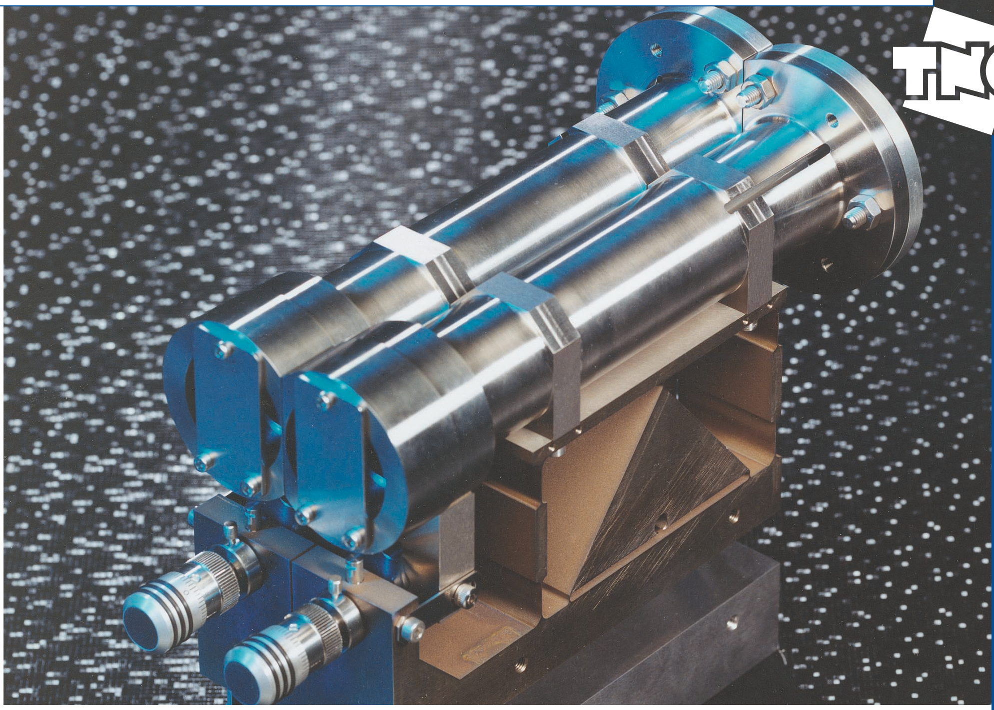
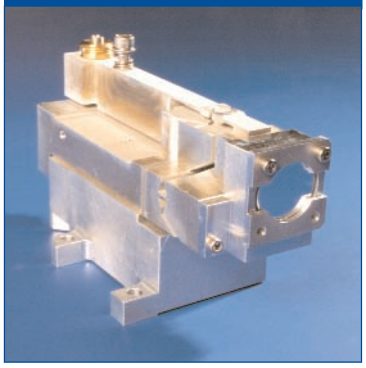
TNO TPD

Nulling interferometry breadboard



TNO TPD delivers innovative and complete solutions for large companies, SMEs and the government.
Our fields of knowledge are: acoustics and vibrations, models and processes, and imaging and instrumentation.
Projects, both national and international, vary from system development to consultancy.



Fine alignment mechanics

Nulling interferometry is a direct method to detect earth-like planets.
To determine whether a planet is earth-like spectrometry can be performed which requires a broadband optical input signal from the planet.
The star signal is roughly 10^6 times stronger than the planet signal.
Nulling interferometry should decrease the broadband ($\lambda \approx$ 6-18 μm) star signal by about this factor 10^6.

For an ESA contract a nulling interferometer breadboard has been designed, manufactured and tested by TNO TPD as subcontractor of Astrium Germany.
Final measurements are being performed from December 2002 until April 2003 by Astrium Germany.

The set-up enables testing of two different phase shifters (one based on dispersive phase shifting and one on field reversal by reflections), two different source designs (one amplitude division and one wavefront division) and consists of three sources, a star source, a planet source and a control source. The optical path difference is actively stabilized using an adaptive control scheme and a piezo activated cat's-eye delay line.

Optical design

Delay lines

The used delay lines have been designed and manufactured by TNO TPD. They consist of a two-mirror set-up, one parabolic mirror and at its focal plane a flat mirror. This flat mirror is mounted on a piezo allowing sub-nm control of optical path difference (OPD).
The beam combination is performed by a Sagnac scheme allowing a highly symmetric beam combination necessary for deep nulling.

Mechanical design

Alignment mechanisms

All alignment mechanisms can be locked without noticeable influence on setting point. They are highly stable and provide

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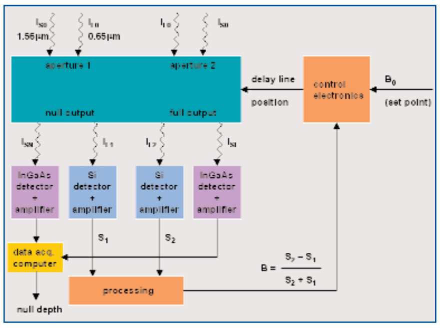
Nulling interferometry breadboard

high resolution (< 0.5 mrad). They have been designed by the mechanical department of TNO TPD.

Control design

The OPD control scheme is necessary to stabilize the optical path length difference of the nulling beams to a certain value with an accuracy of < 1 nm. A visual beam is added in the set-up, which follows the same path as the near-infrared nulling beams ensuring proper OPD measurement. The dispersive phase shifter shifts these beams over 90°; the two interferometer outputs are 90° out of phase with respect to the nulling beams. This ensures highly sensitive and directional sensitivity control around the nulling set point.



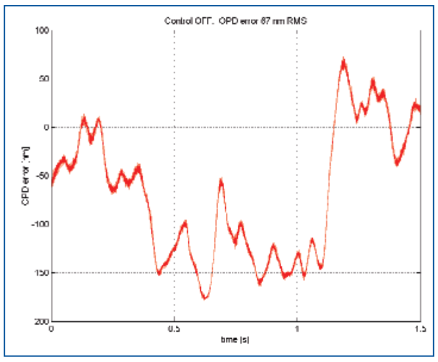
Controlling the null depth by using visible beams.

The controller has the following features:

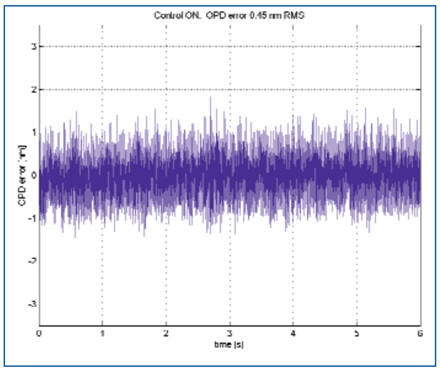
- Digital; for reasons of flexibility and accuracy
- A high clock frequency of 12 kHz to limit the loop delay
- The controller is adaptive such that it is robust to uncertainties in disturbance and plant models and it is able to track variations in the disturbance.

Test results

The bandwidth of one star source equals 1550 ± 15nm. First tests at TNO TPD with this source resulted in an optical path length stability of 0.5 nm RMS and a repeatable stable nulling depth of 30000 ($3.3 \cdot 10^{-5}$) and a maximum obtained nulling depth of 36000 ($2.8 \cdot 10^{-5}$).
Another test performed at Astrium with a 1306 nm DFB laser source with bandwidth 0.1 nm yielded a repeatable stable (2 hours) nulling depth of 100000 ($1.0\ 10^{-5}$) up to 200000 ($5.0\ 10^{-6}$). The adaptive controller clearly outperforms a regular PID controller.



Control system switched off:
- Gives an unstable null



Control system switched on.
- With the adaptive controller in operation gives a stable null.

TNO TPD

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