HIFI Diplexer Calibration

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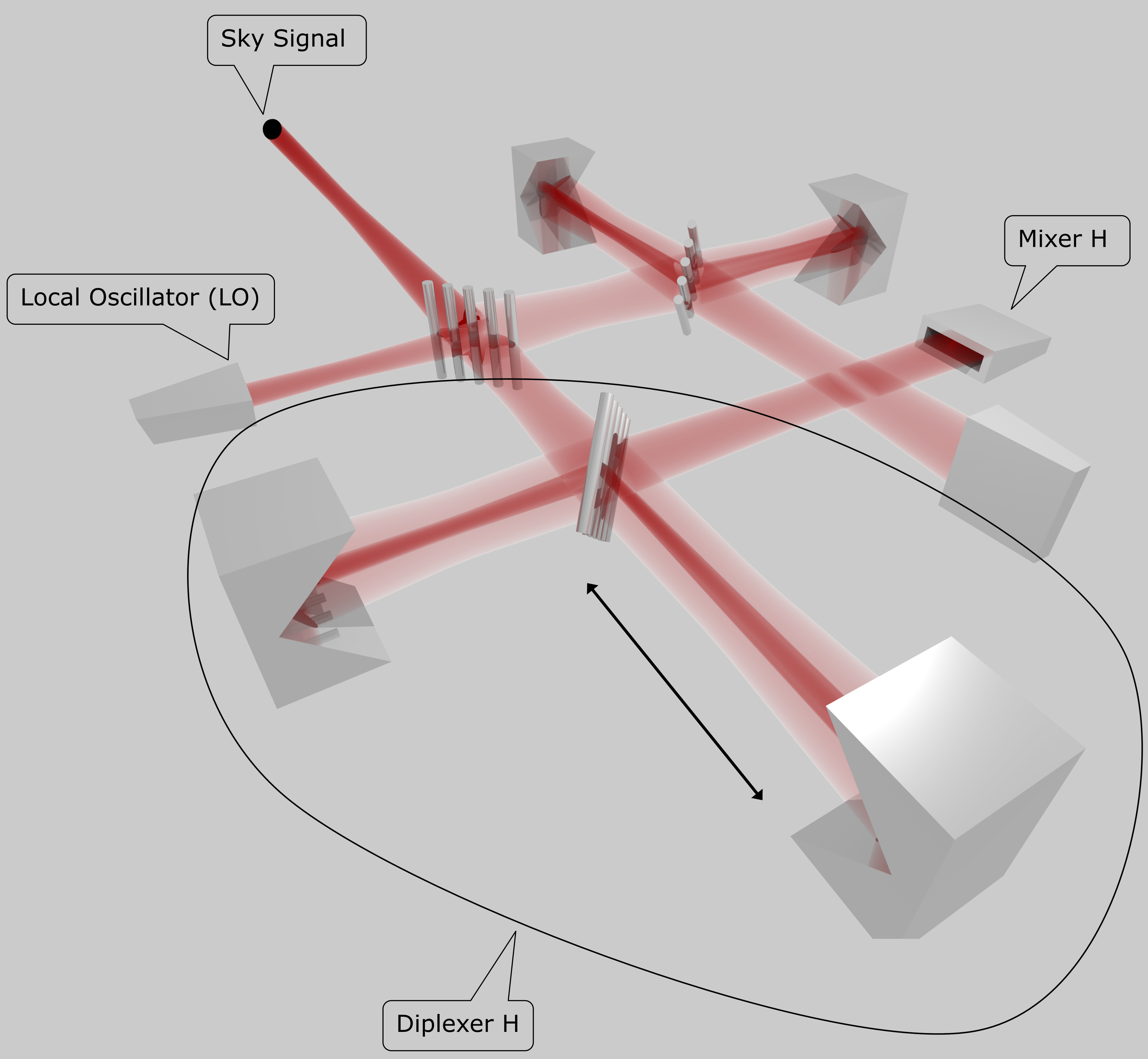
Abstract

HIFI has independent linearly polarized signal chains (H and V). Sky signal and local oscillator (LO) must be combined and polarized before entering the mixers. Where possible (bands 1, 2, 5), beamsplitters are employed, which need no in-flight tuning but lose ~90% of the LO power. Bands 3, 4, 6, 7 use diplexers, which make full use of LO power but need in-flight tuning.

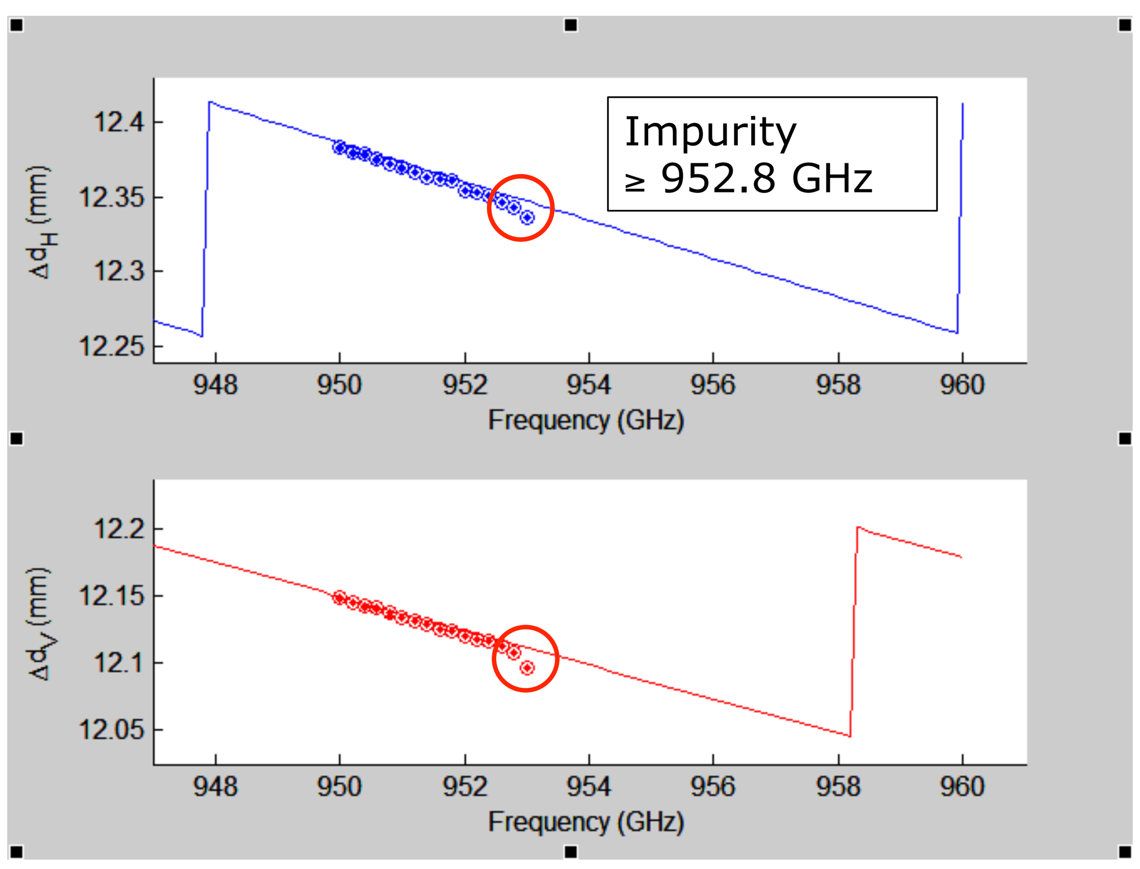
From test observations taken throughout the mission, we show that the optical path difference (OPD) is reproducible at the sub-micron level (<0.2% of the relevant wavelength). Diplexer calibration does not inject any appreciable uncertainty into science data.

Due to their excellent calibration, the diplexers can be used as Fourier transform spectrometers to check the spectral purity of the LO.



Cool stuff: diplexers as FTS

The interference pattern is so predictable, deviations from the expected behavior can be used to diagnose spectral impurities in the LO!

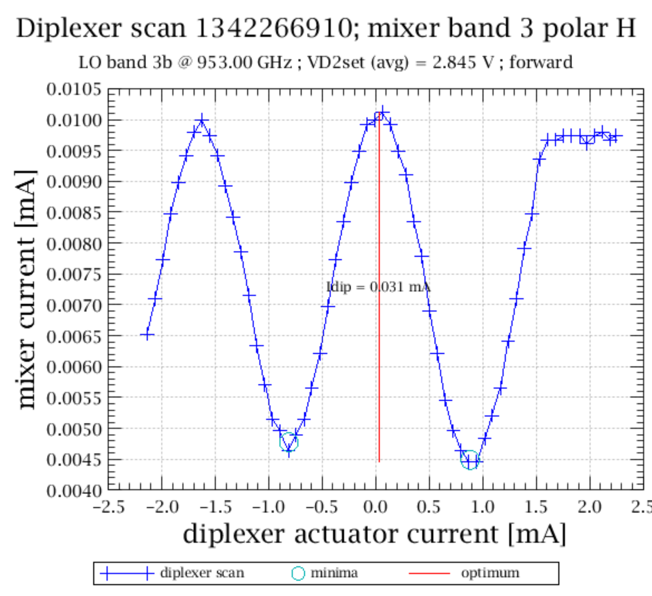


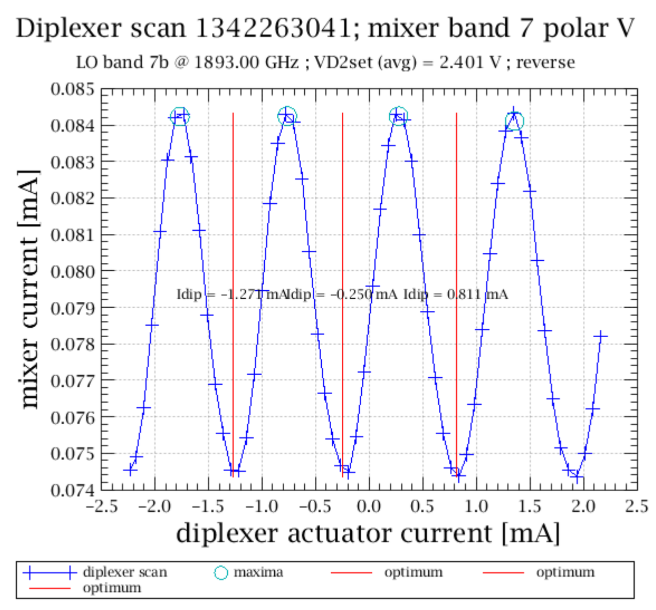
Diplexers: what do they do?

LO and sky signal are combined using a polarizing grid. Afterwards, sky and LO are polarized orthogonally. Polarization must be co-aligned before coupling to mixers (H, V). Bands 3, 4, 6, 7 employ diplexers (H, V) for that; all eight diplexers share the same Martin-Puplett interferometer design (see figure left):

- Polarizing grid at 45°
- 2 rooftop mirrors, one of which can be moved (OPD)
- Produces linearly polarized output
- Interference pattern: optimum coupling if
  - Sky: OPD = n*wavelength
  - LO: OPD = (n+½)*wavelength

- Rooftop mirror moved by rotational actuator (not depicted).
- No control loop: actuator current is commanded, no feedback.
- Distance pivot—mirror = 27.5 mm ~ 100's of wavelengths, OPD well described by 2nd order polynomial in actuator current.
- For science observations: use one look-up table per diplexer with actuator current per frequency.





Sample diplexer scans: coupling vs. OPD for the whole range in actuator current (OPD). Note the shorter wavelength in band 7.

Results:

Diplexer calibration is checked quarterly through engineering obs that scan the actuator range for each diplexer, for various frequencies, LO parameters, and mixer parameters (see Table below).

- Best-fit tuning parameters remarkably stable
- Inferred maximum OPD offset is 333nm. Wavelength > 150μm, i.e., OPD offset < 0.2% wavelength
- After cycle 60, we found diplexer cal so repeatable, the parameter range scanned was cut significantly. Observation duration went down from ~1.5hr per band to ~9 min per band, i.e., by factor of 10.

	Band 3				Band 4				Band 6				Band 7			
	beta_H	beta_V	d0_H	d0_V	beta_H	beta_V	d0_H	d0_V	beta_H	beta_V	d0_H	d0_V	beta_H	beta_V	d0_H	d0_V
QSFT-0	0.1975	0.2156	12.3353	12.1231	0.1721	0.1793	12.3490	12.5395	0.1734	0.2100	21.0532	20.8718	0.1661	0.1586	20.7955	20.7667
QSFT-1	0.1975	0.2155	12.3353	12.1231	0.1722	0.1791	12.3490	12.5396	0.1741	0.2100	21.0534	20.8716	0.1661	0.1587	20.7955	20.7666
QSFT-2	0.1977	0.2156	12.3355	12.1231	0.1722	0.1791	12.3490	12.5395	0.1733	0.2100	21.0532	20.8719	0.1661	0.1586	20.7955	20.7666
QSFT-3	0.1976	0.2155	12.3354	12.1231	0.1723	0.1790	12.3491	12.5395	0.1734	0.2100	21.0534	20.8720	0.1661	0.1587	20.7954	20.7666
QSFT-4	0.1975	0.2155	12.3353	12.1232	0.1722	0.1792	12.3491	12.5395	0.1735	0.2100	21.0531	20.8717	0.1662	0.1587	20.7955	20.7667
QSFT-5	0.1977	0.2155	12.3355	12.1232	0.1722	0.1791	12.3490	12.5395	0.1734	0.2100	21.0531	20.8717	0.1661	0.1586	20.7955	20.7666
QSFT-6	0.1976	0.2156	12.3353	12.1231	0.1722	0.1791	12.3491	12.5395	0.1733	0.2100	21.0531	20.8718	0.1662	0.1586	20.7954	20.7666
mean	0.1976	0.2155	12.3354	12.1231	0.1722	0.1791	12.3490	12.5395	0.1735	0.2100	21.0532	20.8718	0.1661	0.1586	20.7955	20.7666
stdev	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0000	0.0003	0.0000	0.0001	0.0001	0.0000	0.0001	0.0000	0.0000
delta	**132**	**75**			**81**	**109**			**333**	**65**			**70**	**75**		
(in nm)	**(3H)**	**(3V)**			**(4H)**	**(4V)**			**(6H)**	**(6V)**			**(7H)**	**(7V)**		
	delta	**worst-case displacement error** (note that the actuator current resolution corresponds to 300 nm)														
	beta	proportionality factor between pivot rotation and actuator current in deg/mA														
	d0	pathlength difference between the two diplexer arms at zero actuator current in mm														
	d =	27.5 mm * pi / 180 * (alpha (beta) * I^2 + beta * I) + d0														