CC demodulation

March 21, 2021

1 Coherent control field at homodyne detector

The CC field provided by the CC laser in the squeezer box and sent to the OPA is

$$E_{CC}(t) = \alpha \cdot \cos(\omega_0 t + \varphi + \Omega) \tag{1}$$

where ω_0 is the carrier frequency and φ the relative phase on which the HD CC loop acts. The nonlinear interaction inside the OPA with the pump field $E_p(t) = \beta \cdot \cos(2\omega_0 + \Phi)$ (Φ is controlled by the pump phase CC loop) generates a second sideband at frequency$-\Omega$; the field at the OPA output becomes (see for instance PhD Chelkowski pag.167).

$$E_{CC}(t) \propto \frac{1+g}{\sqrt{2g}} \cos(\omega_0 t + \varphi + \Omega t) - \frac{1-g}{\sqrt{2g}} \cos(\omega_0 t + \varphi - \Omega t - 2\Phi) \tag{2}$$

where g is the OPA parametric gain. This field produces a beat note with the LO $E_{LO} = \gamma \cdot \cos(\omega_0 t)$ at the homodyne detector. The beat note $B(t)$ at frequency Ω is

$$B(t) \propto (1+g)\cos(\Omega t + \varphi) - (1-g)\cos(-\Omega t + \varphi - 2\Phi) \tag{3}$$

The beat note can be written as the sum of an in-phase term B_i and a quadrature term B_q:

$$B(t) \propto B_q \cos(\Omega t) + B_i \sin(\Omega t) \tag{4}$$

where the in-phase term is

$$B_i = -(1+g)\sin(\varphi) - (1-g)\sin(\varphi - 2\Phi) \tag{5}$$

and the quadrature term is

$$B_q = (1+g)\cos(\varphi) - (1-g)\cos(\varphi - 2\Phi) \tag{6}$$

2 CC phase

The phase measured Φ_{meas} after demodulating at Ω is calculated from the ratio of in-phase and quadrature terms:

$$\Phi_{meas} = \arctan \frac{B_i}{B_q} = \arctan \frac{-(1+g)\sin(\varphi) - (1-g)\sin(\varphi - 2\Phi)}{(1+g)\cos(\varphi) - (1-g)\cos(\varphi - 2\Phi)} \tag{7}$$

The relation between Φ_{meas} and the actuation phase φ is not linear, unless the OPA nonlinear interaction is negligible, i.e. g=1.

3 Magnitude of beat note

The magnitude of the beat note is calculated as the quadrature sum of the two terms:

$$M = \sqrt{B_i^2 + B_q^2} \propto \sqrt{2[1 + g^2 - (1-g^2)\cos(2\varphi - 2\Phi)]} \tag{8}$$

The magnitude oscillates with the phase difference $\varphi - \Phi$. In particular, the ratio of maximum and minimum magnitude equals the parametric gain g.