On the cSQZ power fluctuations

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I compute the impact of a fluctuation of power at the input IR to the cSQZ, on the produced SQZ and NLG down the line.

Let P_{IR} [Watt] the input IR power to the SHG. The nonlinear process creates a green beam whose power is P_{GR} [Watt] such that

$$P_{GR} = G_{SHG} \times P_{IR}^2 \tag{0.1}$$

where G_{SHG} [Watt^{-1}] is a constant (equation 4.19 of Alvaro's thesis).

The OPO is pumped by the green power. To estimate how much squeezing is produced, consider the measurement where the CLF is put at the frequency of the 1064nm carrier and we measure the transmitted power through the OPO, on resonance, when there is non-linear amplification or not. Let P_{OPOa} [Watt] and P_{OPO0} [Watt] be the transmitted power when there is and isn't amplification respectively. The ratio of these powers is the classical nonlinear gain of the OPO G_{OPO} (equation 3.45 of Sheila's thesis):

$$G_{OPO} = \frac{P_{OPOa}}{P_{OPO0}} = \frac{1}{(1-x)^2} \tag{0.2}$$

where $x = \sqrt{P_{GR}/P_{th}}$ is the ratio of the pump *amplitude* to threshold. The amount of produced squeezing and antisqueezing in variance units are (equations 2.27 and 2.28 of Eric's thesis)

$$V_{SQZ} = \frac{(1-x)^2}{(1+x)^2} = \frac{1}{(2\sqrt{G_{OPO}}-1)^2}, \qquad V_{aSQZ} = \frac{1}{V_{SQZ}} = (2\sqrt{G_{OPO}}-1)^2 \tag{0.3}$$

and the produced squeezing levels in dB from shot noise

$$dB_{SQZ} = -20\log_{10}(2\sqrt{G_{OPO}}-1), \qquad dB_{aSQZ} = -dB_{SQZ} = 20\log_{10}(2\sqrt{G_{OPO}}-1) \tag{0.4}$$

I now apply these formulas to realistic power fluctuations on the input IR. In practice, we are suffering from power fluctuations on P_{IR}, such that $P_{IR} = P_{IR0}(1+\epsilon)$ where $P_{IR0} \sim 60$ mW but most importantly $\epsilon \sim 10\%$. This means that, with the notation $P_{GR0} = G_{SHG}P_{IR0}^2$, we have

$$P_{GR} \in [0.81,\ 1.21] \times P_{GR0} \tag{0.5}$$

In other words, since $(1+\epsilon)^2 \simeq 1+2\epsilon$, **the power fluctuations on the Green are twice that of the input IR**.

Experimentally, we can tune the OPO so that the average classical NLG is $G_{OPO0} \sim 10$, defined by $G_{OPO} = 1/(1-x_0)^2$, where $x_0 = \sqrt{P_{GR0}/P_{th}} \sim 0.68$ is the average pump amplitude ratio. Then, because of $\epsilon \sim 10\%$, one has

$$G_{OPO} \in [6.8,\ 16.3] \tag{0.6}$$

This translates into large power fluctuations of the CLF amplified beam when it has no frequency offset from the carrier. Furthermore, in terms of produced antisqueezing,

$$dB_{aSQZ} \in [12.5,\ 17] \tag{0.7}$$

The two figures below sum up this issue for different values of ϵ, at the fixed value of $G_{OPO0} = 10$. The shaded area corresponds to the attainable values.

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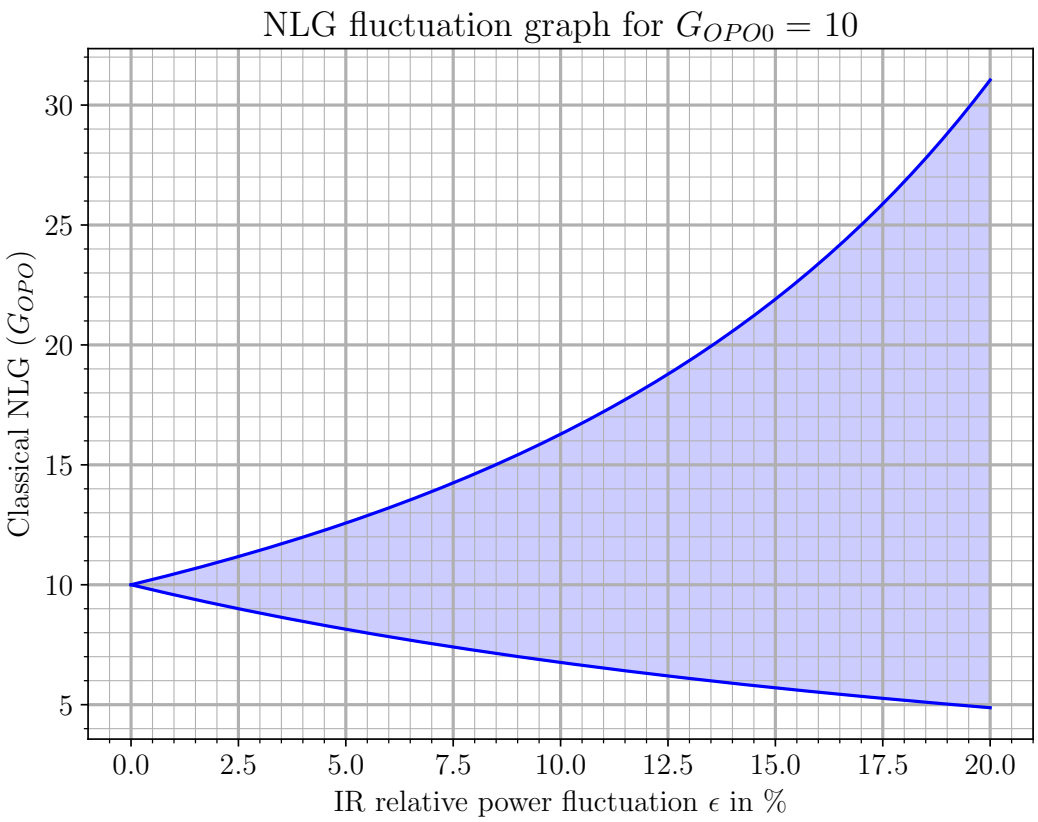
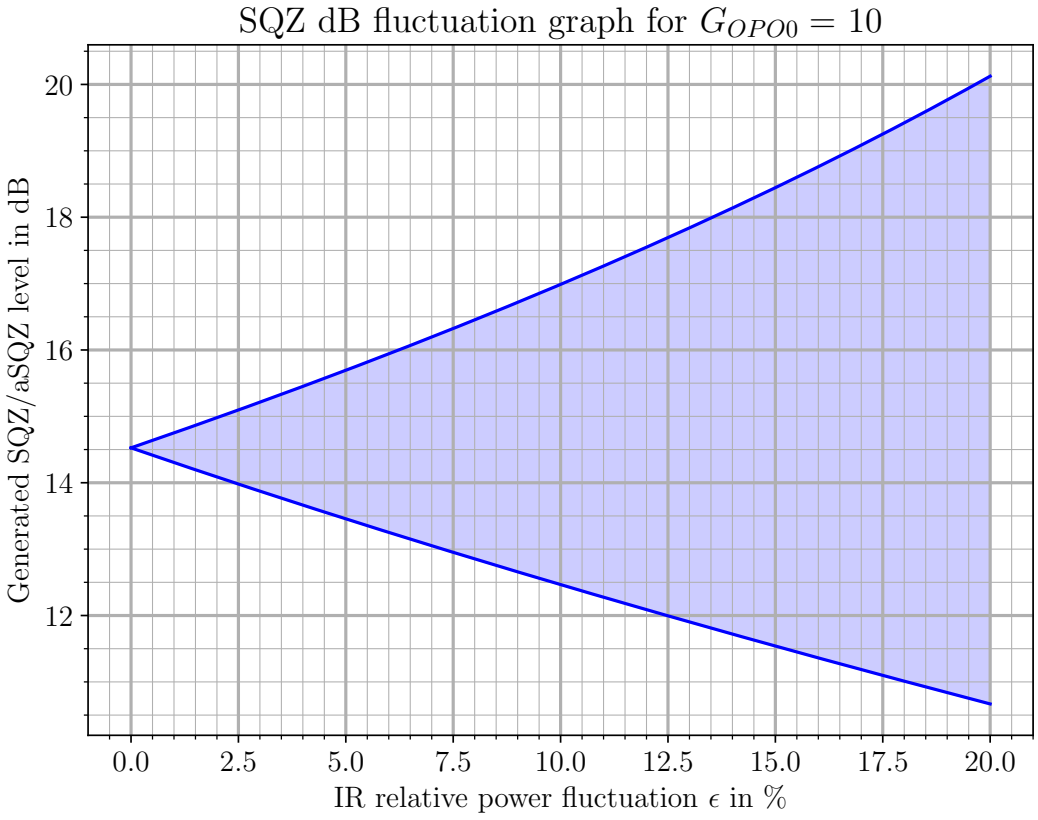

NLG fluctuation graph for $G_{OPO0} = 10$
Classical NLG (G_{OPO})
30
25
20
15
10
5
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
IR relative power fluctuation ϵ in %


SQZ dB fluctuation graph for $G_{OPO0} = 10$
Generated SQZ/aSQZ level in dB
20
18
16
14
12
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
IR relative power fluctuation ϵ in %