Modelling adVirgo ASC loops with Finesse

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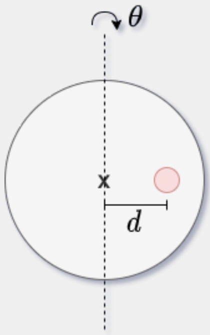
Context

Modeling goal: determining how much angular motion in the detection frequency band ($f > 10$Hz) is converted into DARM motion.

In a bilinear process, the residual angular motion is modulated by the beam spot motion and produces a length signal:

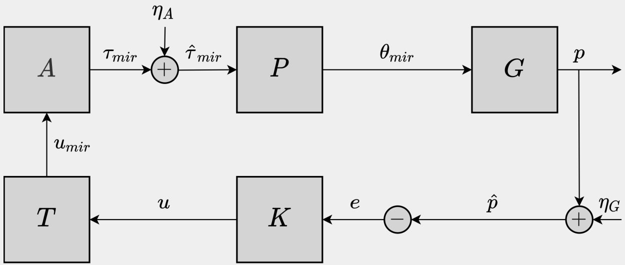
$$x(\theta) = d(\theta) * \theta$$



Three ingredients are needed:

- the residual angular motion of the mirrors θ
- the beam miscentering on each mirror d
- the noise sources η

$$x(\theta(\eta)) = d(\theta(\eta)) * \theta(\eta)$$



We need a tool that can handle the ASC MIMO system and include the response of the full interferometer.

Finesse 3.0

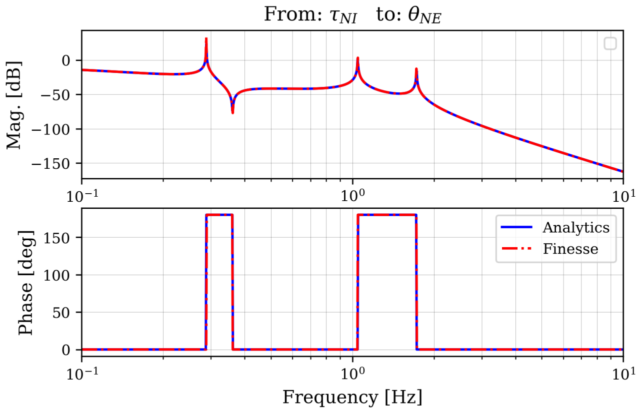
Development of new Finesse version https://gitlab.com/ifosim/finesse/finesse3.

- Modern Python-based code based.
- New integration: **electrical+mechanical systems** (control loops).
- It includes the optical response of the **full interferometer** (which depends upon the defects).

- Beta version will be out in November and ready for wider use by people.

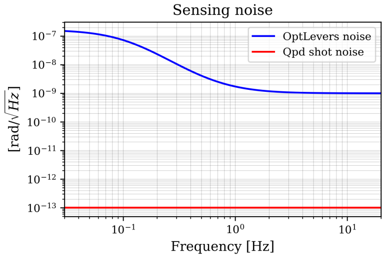
To work out the residual angular motion (and the beam miscentering) of the mirrors we need:

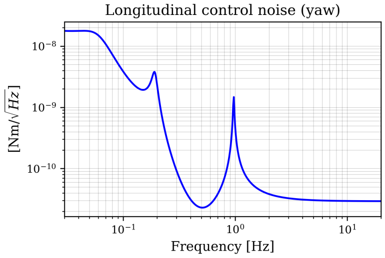
- a model of the opto-mechanical plant
- the full ASC control scheme.



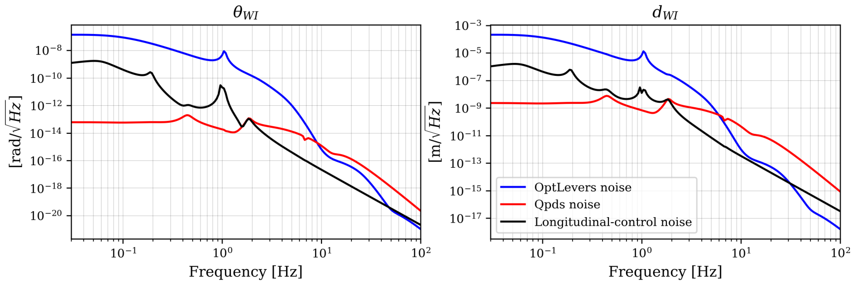
An element of the opto-mechanical plant

- OptLevers noise: obtained from data.
- Qpds shot noise: obtained from data.
- Longitudinal control noise: semi-empirical model based on data.



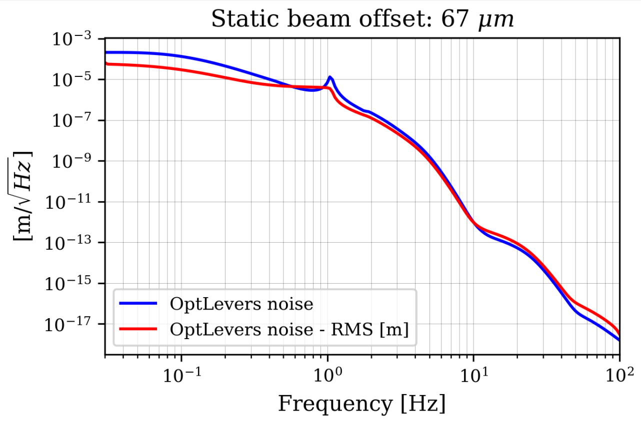


The input noises have been propagated across the model to compute the residual **mirror motion** and the consequent **beam miscentering**.



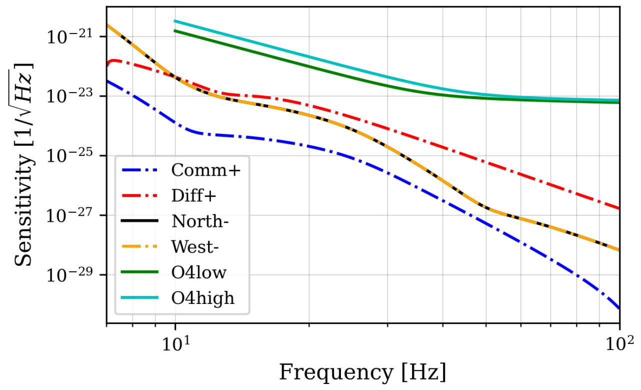
WI residual angular motion due to input noises (left). Beam miscentering on WI due to input noises (right).

$$x(t) = d(t) * \theta(t) \quad \rightarrow \quad x(t) \approx d_{\text{RMS}}\theta(t)$$



The static beam offset is: 67μm.

DARM motion due to angular control depends upon the direction of the of the miscentering onto each mirror. **We are showing the worst case scenario**.



The control strategy is that used during O3, the sensitivities are those for O4.

- A model of adVirgo ASC loops that includes the optical response of the full interferometer has been realised using a single tool: **Finesse 3.0**.
- The model has been cross-compared with Octopus, finding a perfect agreement.
- **AdVirgo is not limited by angular control noise.**

Thanks for your attention!

To introduce angular-longitudinal coupling, the static beam offset calculated in the previous slide has been applied to each mirror in these configurations:

	NI	**NE**	**WI**	**WE**
Dp	$+d_{\mathrm{RMS}}$	$-d_{\mathrm{RMS}}$	$-d_{\mathrm{RMS}}$	$+d_{\mathrm{RMS}}$
Cp	$+d_{\mathrm{RMS}}$	$-d_{\mathrm{RMS}}$	$+d_{\mathrm{RMS}}$	$-d_{\mathrm{RMS}}$
Nm	$+d_{\mathrm{RMS}}$	$+d_{\mathrm{RMS}}$	0	0
Wm	0	0	$+d_{\mathrm{RMS}}$	$+d_{\mathrm{RMS}}$

In the "time-domain system", the static arrangement of beam offsets will vary among these four configurations.

$$\begin{bmatrix} \theta_{Dp} \\ \theta_{Cp} \\ \theta_{Nm} \\ \theta_{Wm} \end{bmatrix} = \begin{bmatrix} 0.64 & 0.76 & -0.64 & -0.76 \\ 0.64 & 0.76 & 0.64 & 0.76 \\ 0.76 & 0.64 & 0 & 0 \\ 0 & 0 & 0.76 & 0.64 \end{bmatrix} \cdot \begin{bmatrix} \theta_{NI} \\ \theta_{NE} \\ \theta_{WI} \\ \theta_{WE} \end{bmatrix}$$

Each row of the change-of-base matrix above is an eigenvector of the opto-mechanical plant stiffness matrix.

- **Dp:** differential tilt between the two cavities.
- **Cp:** common tilt between the two cavities.
- **Nm:** shift of the North cavity.
- **Wm:** shift of the West cavity.