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On the plane, I worked out calibration voltages per unit displacement on Arm 1 of 40 meter IFO. I get a clear, factor-of-two difference between recombination & old setup. Basically it arises because half the calibration

cc: displacement goes to common-mode servo and does not appear at the DIFE OUT. The servo gains have no effect as long as feed back to laser dominates.

—Fred

Some Notes on Interferometer Calibrations

FJR
5/23/96

Define $\ell_+ = \frac{1}{2}(\ell_1 + \ell_2)$

$\ell_- = \frac{1}{2}(\ell_1 - \ell_2)$

Consider an applied $\delta\ell_1$ with $\delta\ell_2 = 0$ and evaluate response at frequencies above common-mode, coil-driver crossover.

$$\Rightarrow \left.\begin{array}{l} \delta\ell_+ = \frac{1}{2}\,\delta\ell_1 \\ \delta\ell_- = \frac{1}{2}\,\delta\ell_1 \end{array}\right\} \text{are perturbations}$$

Servo outputs are (assume BS @ proper position) in general:

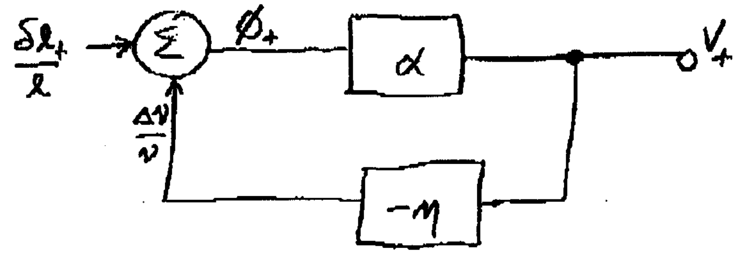
$$V_+ = \alpha\left[\frac{\Delta\nu}{\nu} + \frac{\Delta\ell_+}{\ell}\right]$$

$$V_- = \beta\left[\frac{\Delta\nu}{\nu}\cdot\left(\frac{\ell_-}{\ell}\right) + \frac{\delta\ell_-}{\ell}\right]$$

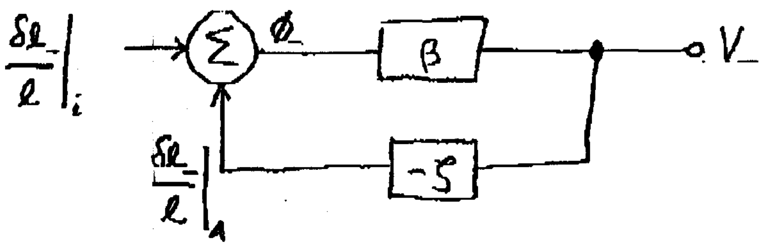
(see following page)

Analysis on following pages shows that a calibration input $\delta\ell_1$ produces half the voltage in the gravitational-wave output compared to the old Mark-II configuration.

Recombined Servo Configuration



Common-Mode Servo



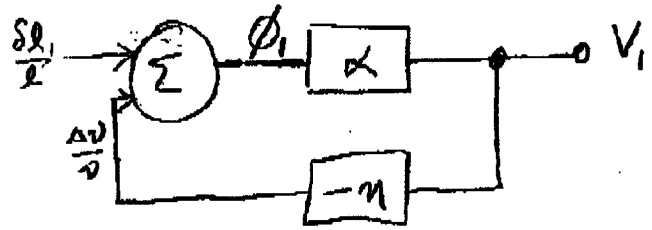
$$V_+ = \alpha\left[-\eta V_+ + \frac{\delta\ell_+}{\ell}\right]$$

$$V_+ = \frac{\delta\ell_+}{\ell}\,\frac{\alpha}{1+\alpha\eta} = \frac{1}{2}\,\frac{\delta\ell_1}{\ell_1}\,\frac{\alpha}{1+\alpha\eta}$$

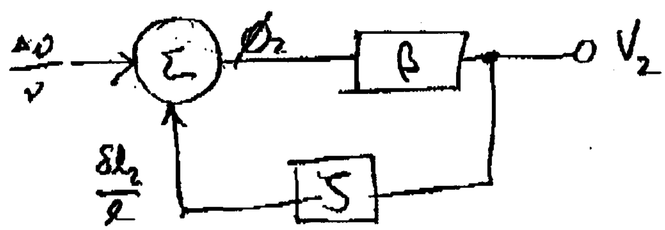
$$V_- \simeq \beta\left[\left.\frac{\delta\ell_-}{\ell}\right|_i + \left.\frac{\delta\ell_-}{\ell}\right|_A\right] = \beta\left[\left.\frac{\delta\ell_-}{\ell}\right|_i - \zeta V_-\right]$$

$$\boxed{V_- \simeq \left.\frac{\delta\ell_-}{\ell}\right|_i \cdot \frac{\beta}{1+\beta\zeta} = \frac{1}{2}\,\frac{\delta\ell_1}{\ell_1}\cdot\frac{\beta}{1+\beta\zeta}}$$

MkII Servo Configuration



Arm 1 "primary"



Arm 2 "secondary"

$$V_1 = \alpha \left[-\eta V_1 + \frac{\delta l_1}{l} \right]$$

$$\Rightarrow V_1 = \frac{\delta l_1}{l} \frac{\alpha}{1 + \alpha \eta}$$

$$V_2 = \beta \left[-\eta V_1 - \zeta V_2 \right]$$

$$(1 + \beta \zeta) V_2 = -\beta \eta V_1 = -\beta \eta \frac{\delta l_1}{l} \frac{\alpha}{1 + \alpha \eta}$$

$$\boxed{V_2 = -\frac{\alpha \eta}{1 + \alpha \eta} \cdot \frac{\delta l_1}{l} \cdot \frac{\beta}{1 + \beta \zeta}}$$

Note $\frac{\alpha \eta}{1 + \alpha \eta} \simeq 1$ for range of interest