

Loss Dependence on Beam Position in the Arm Cavities of aLIGO

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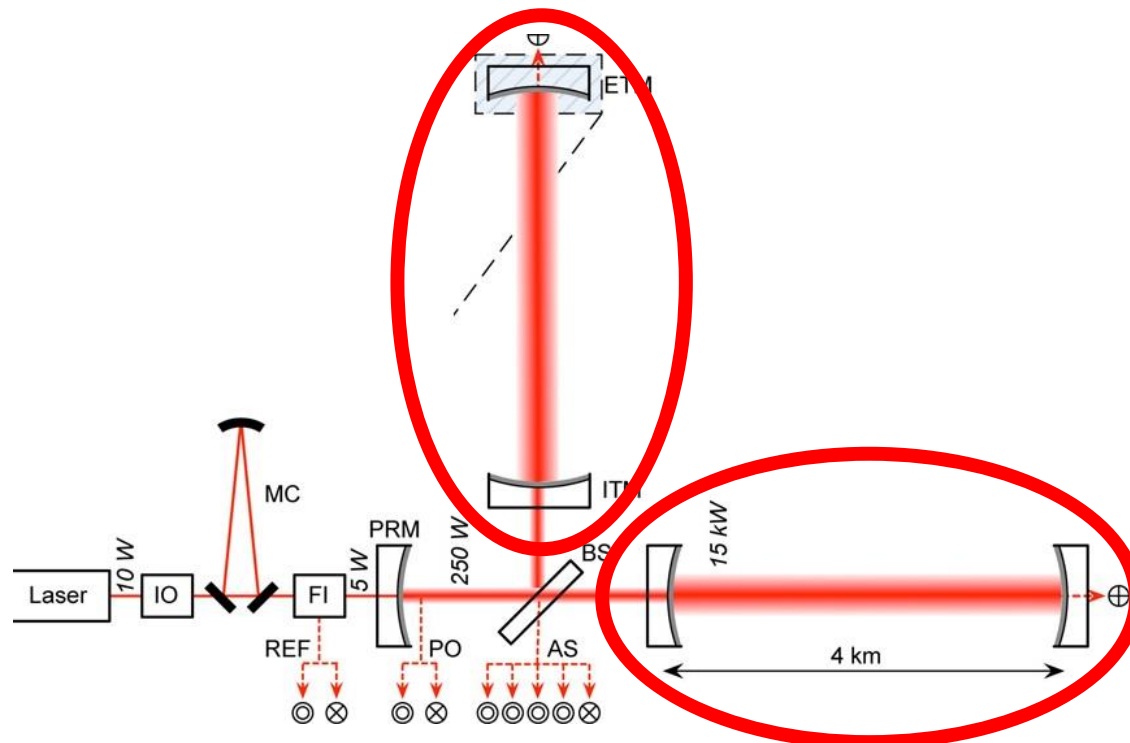
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What did I do?

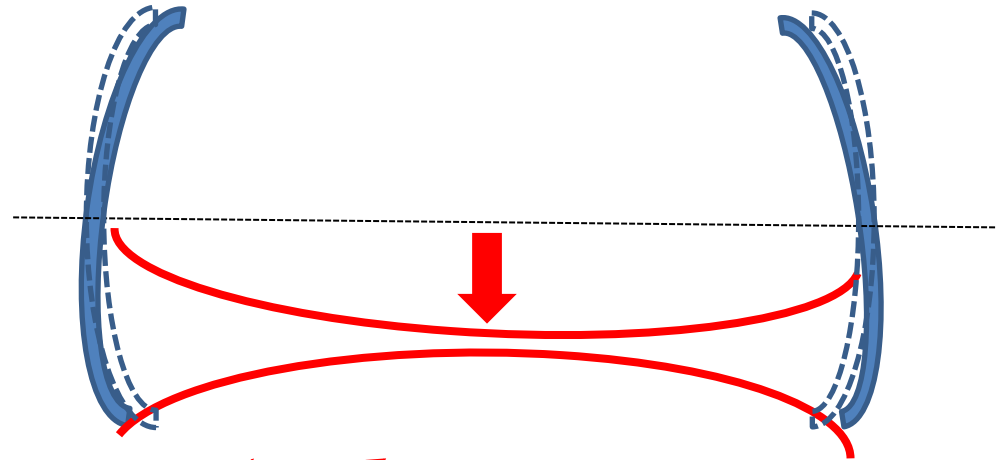
Optical loss in the 4km arm cavities

High cavity power \rightarrow  High sensitivity!!

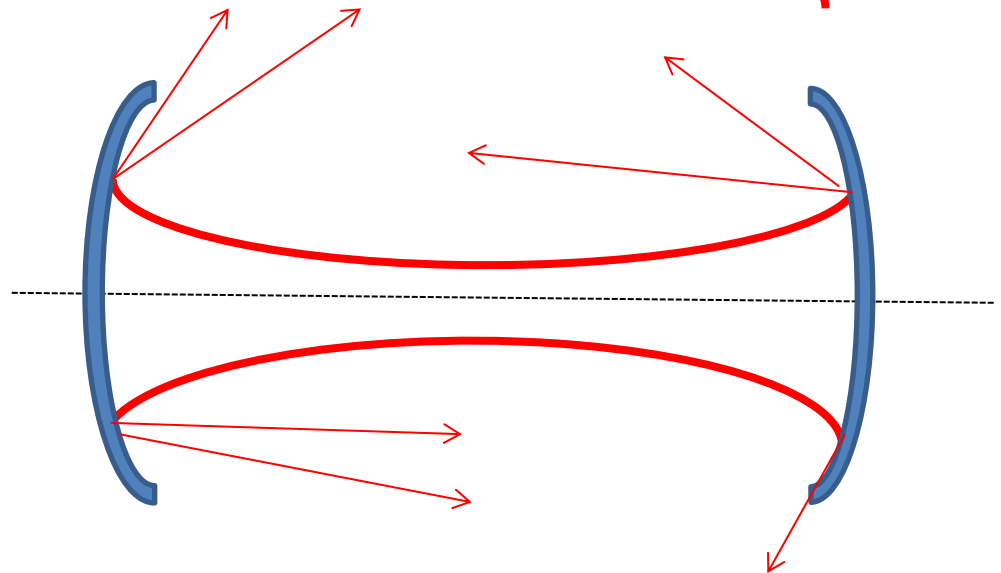


Where do the loss come from?

1 Geometrical loss

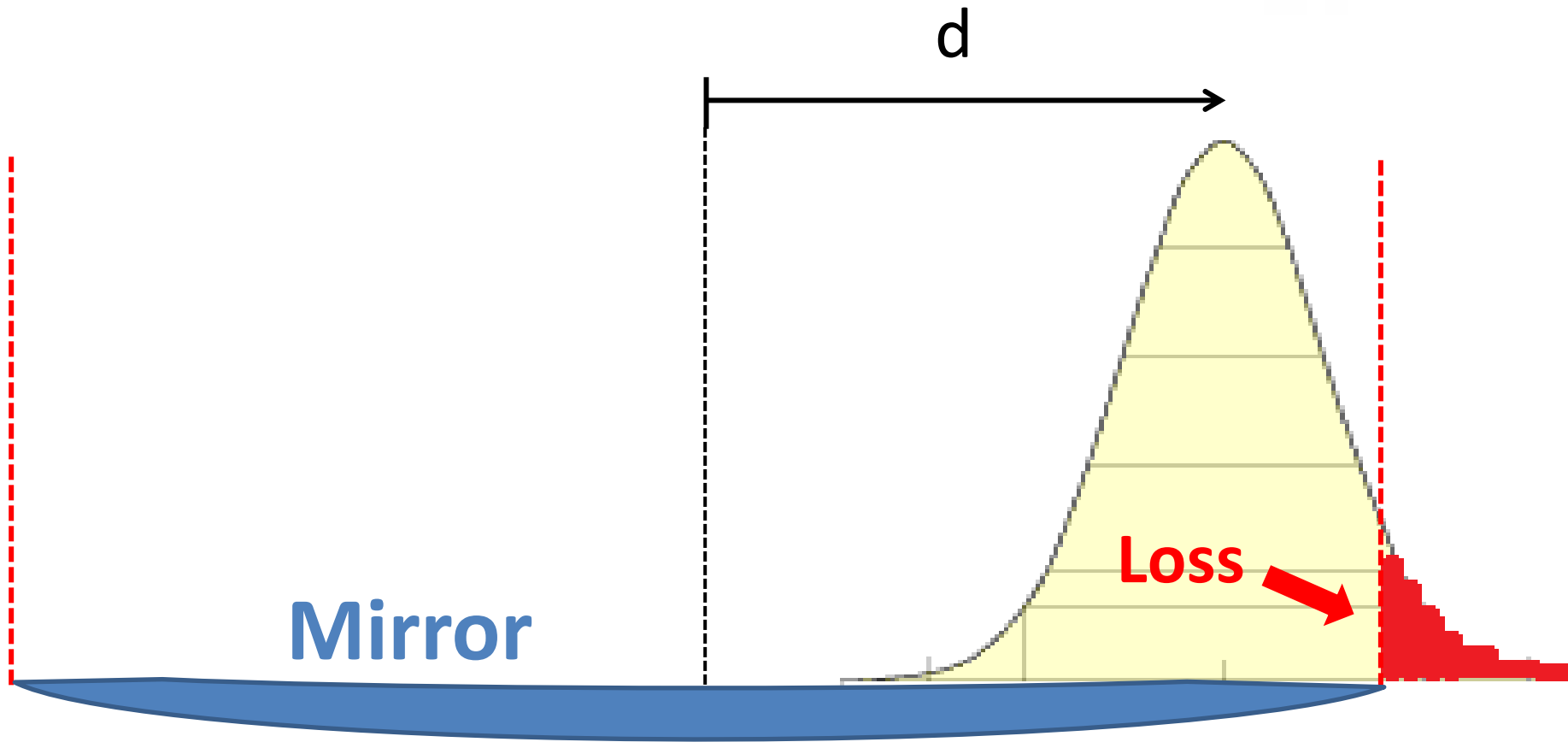


2 Scattering loss



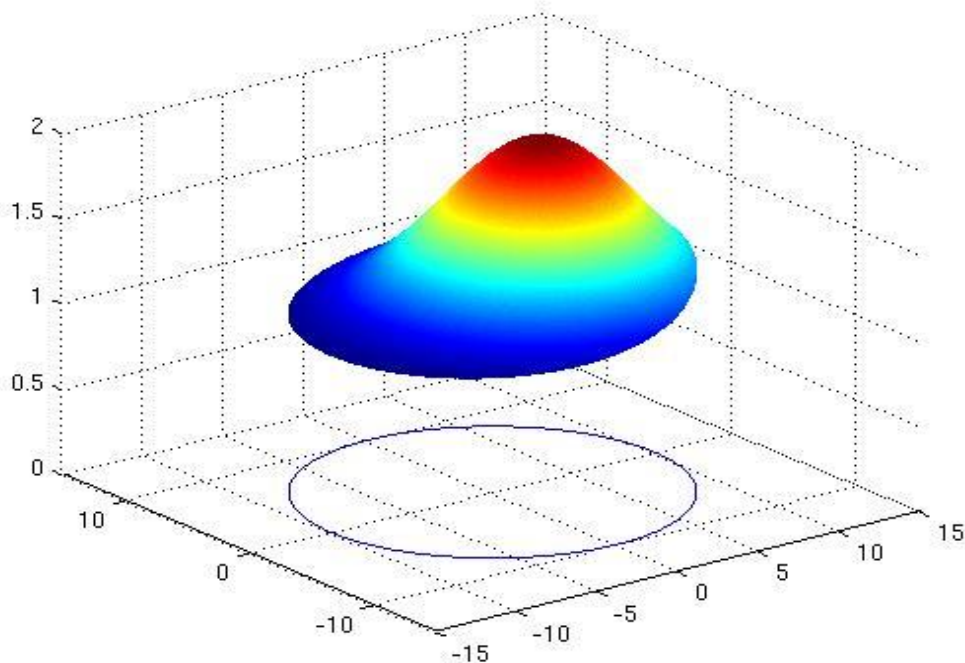
Clipping model : Loss(d)

- TEM00 $u(x, y, z) = E_0 \frac{w_0}{w(z)} \exp\left\{i[kz - \phi(z)] + \left(-\frac{1}{w^2(z)} + i\frac{k}{2R(z)}\right)r^2\right\}$



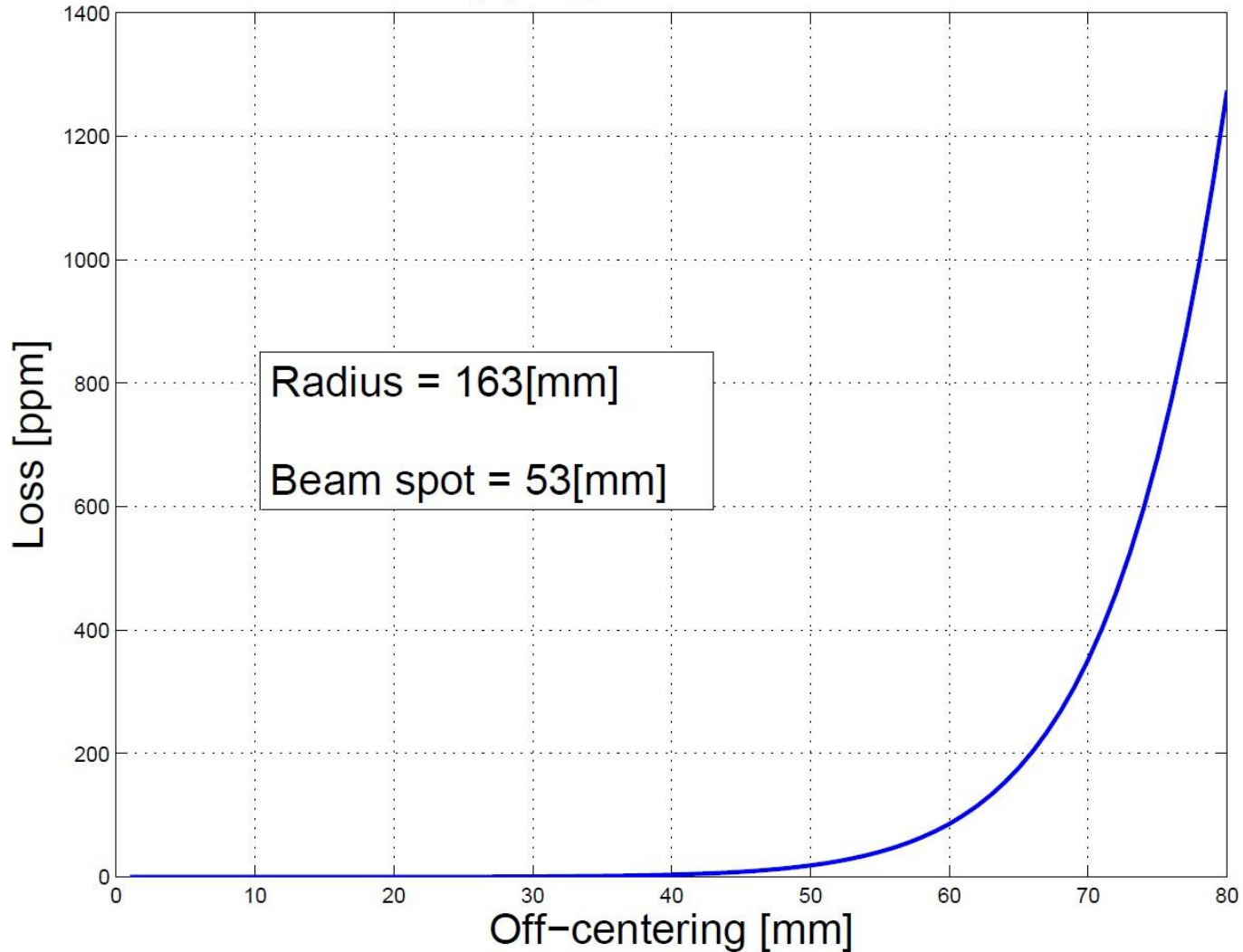
Clipping model : Loss(d)

$$\begin{aligned} L(d) &= 1 - \frac{1}{N} \iint_D dx dy e^{-\frac{2}{w^2}((x-d)^2+y^2)} \quad \text{st } D : x^2 + y^2 \leq R^2 \\ &= 1 - \frac{1}{N} \int_0^R dr \int_0^{2\pi} d\theta r e^{-\frac{2}{w^2}((r\cos\theta-d)^2+(r\sin\theta)^2)} \end{aligned}$$



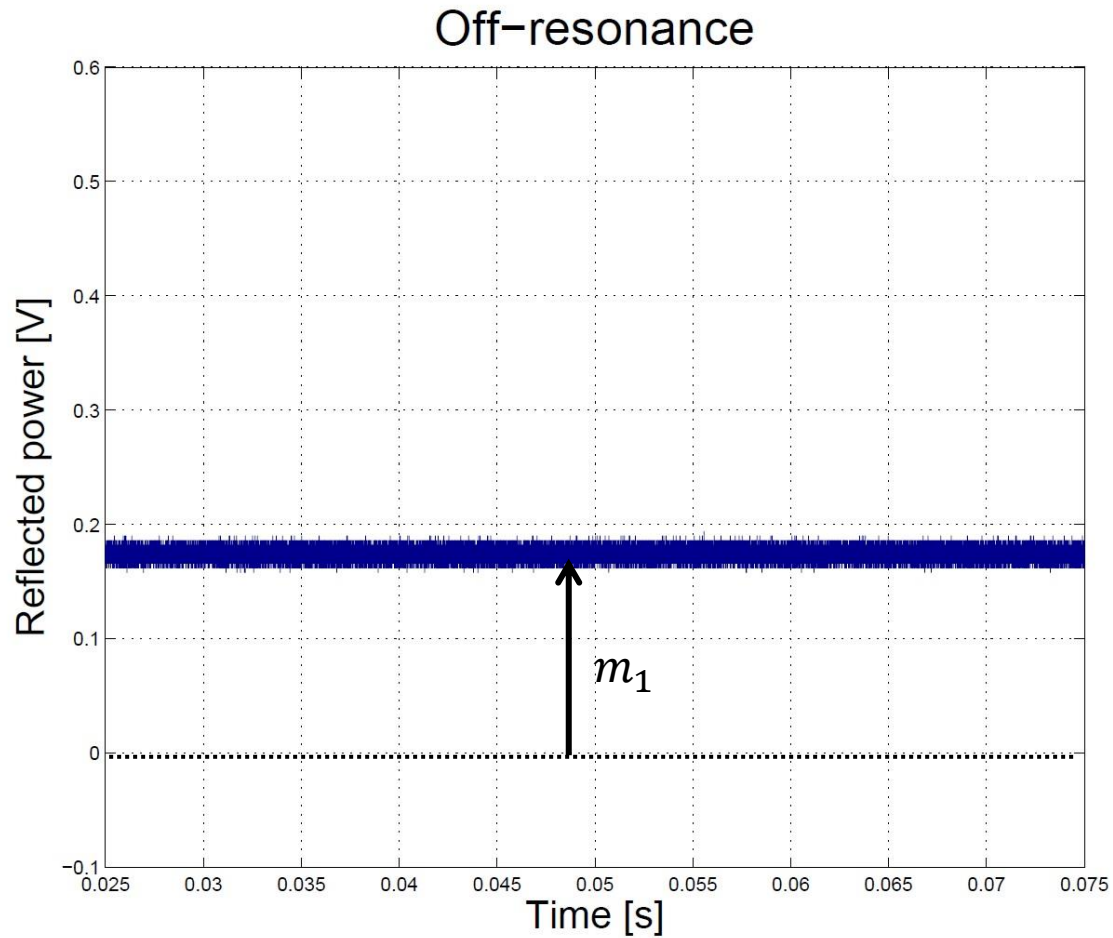
Simulation results

Clipping model of ITM

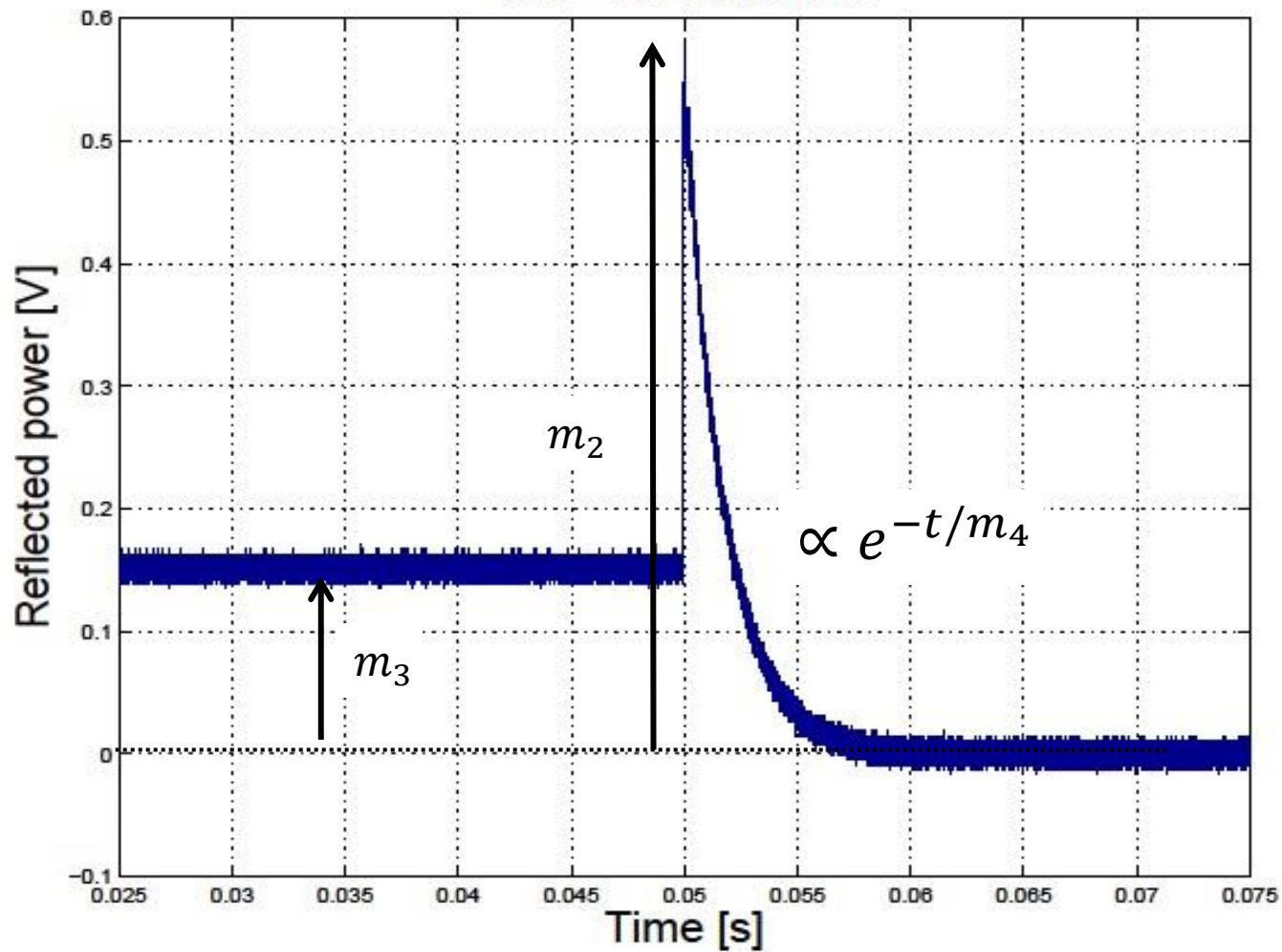


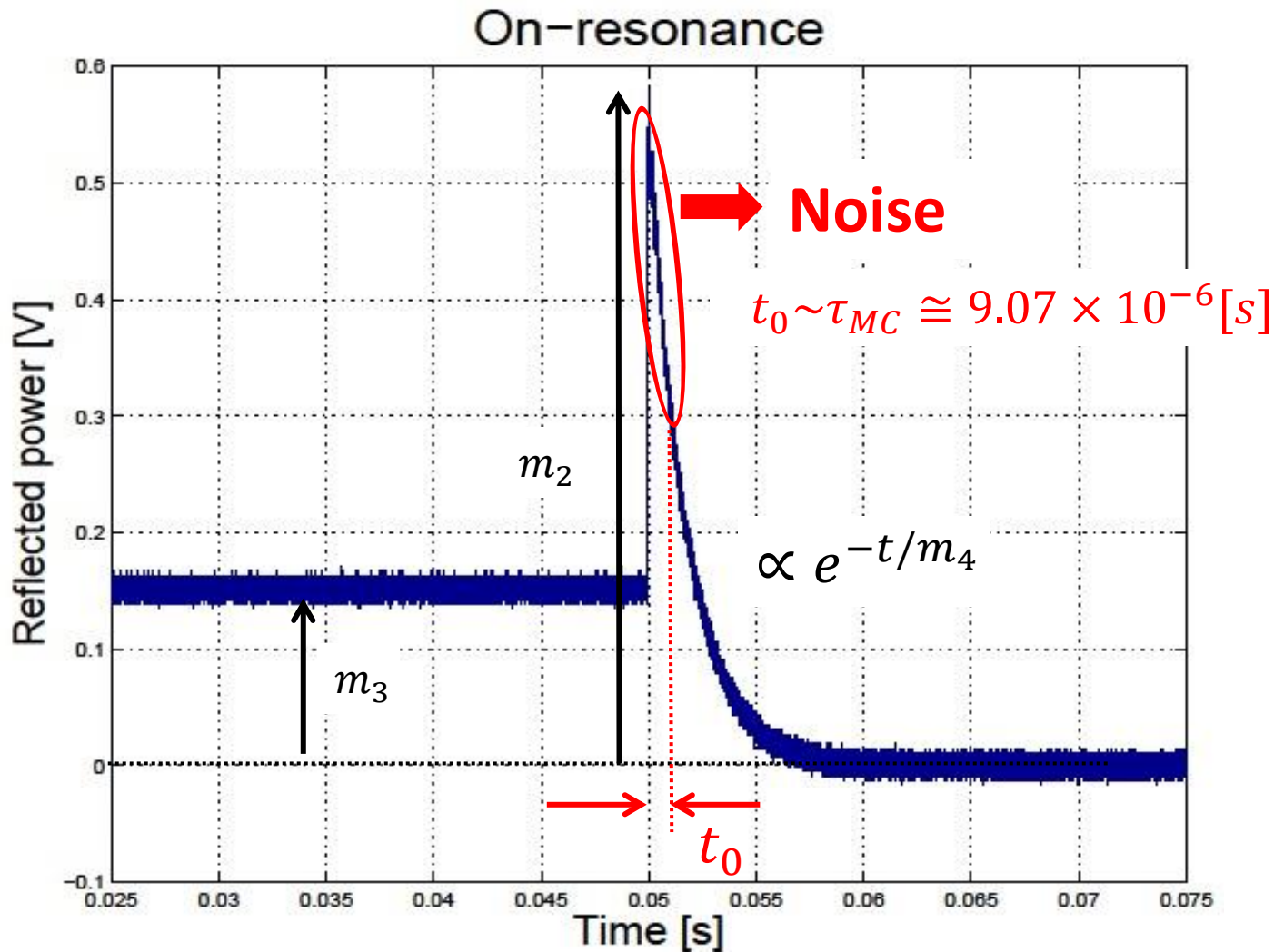
Experiment

- Ringdown method



On-resonance





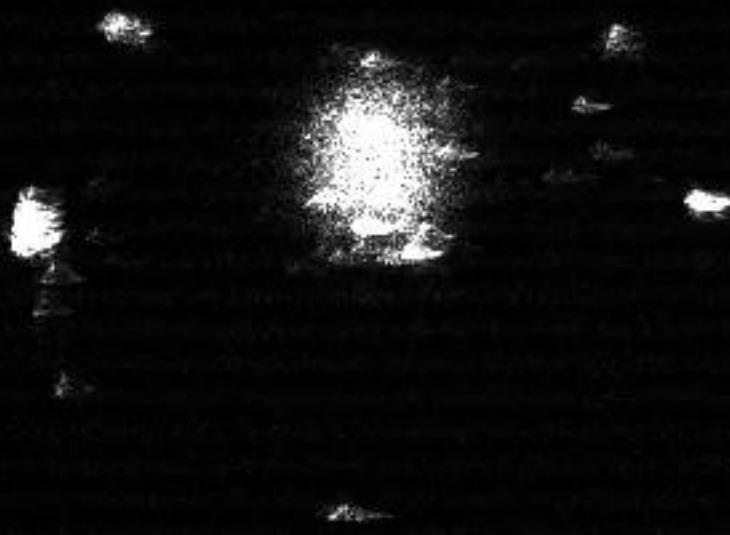
$$m_1, m_2, m_3, m_4 \Rightarrow T_{ITM}, R_{ITM} \Rightarrow L_{rt} = 1 - T_{ITM} - R_{ITM}$$

(cf. Isogai *et al*, Optical Express, Vol.21, No.24(2014))

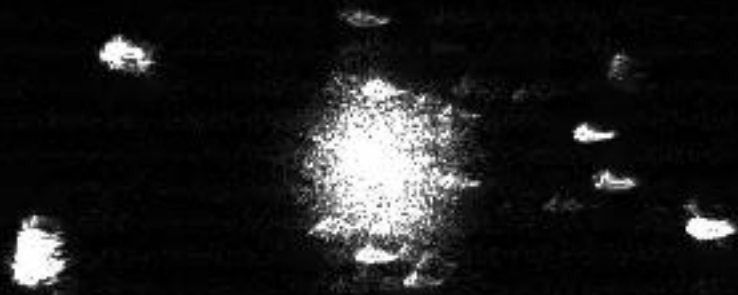
ITMX At 2014-07-21-21-52-54 UTC



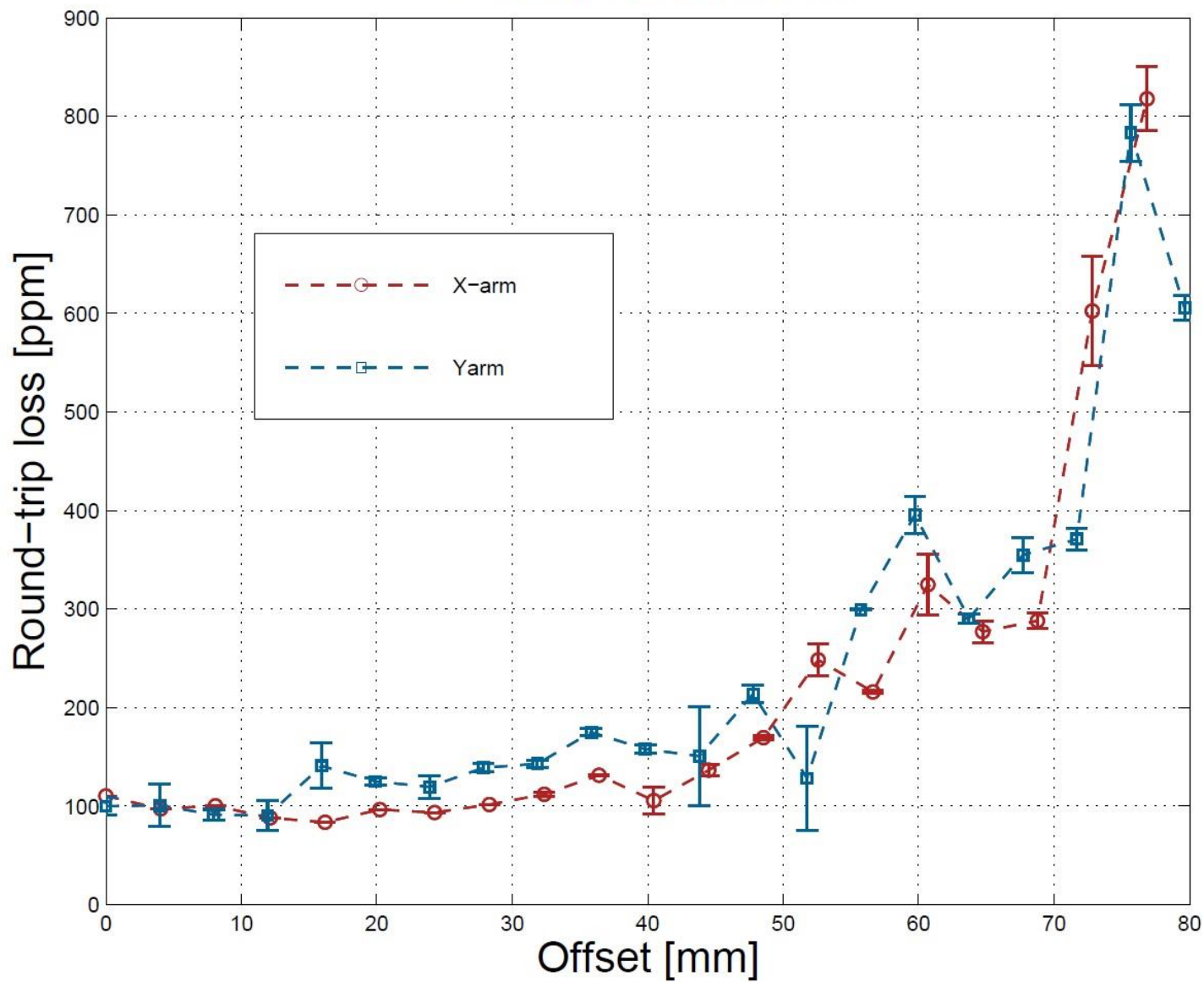
ITMY At 2014-08-16-03-06-43 UTC



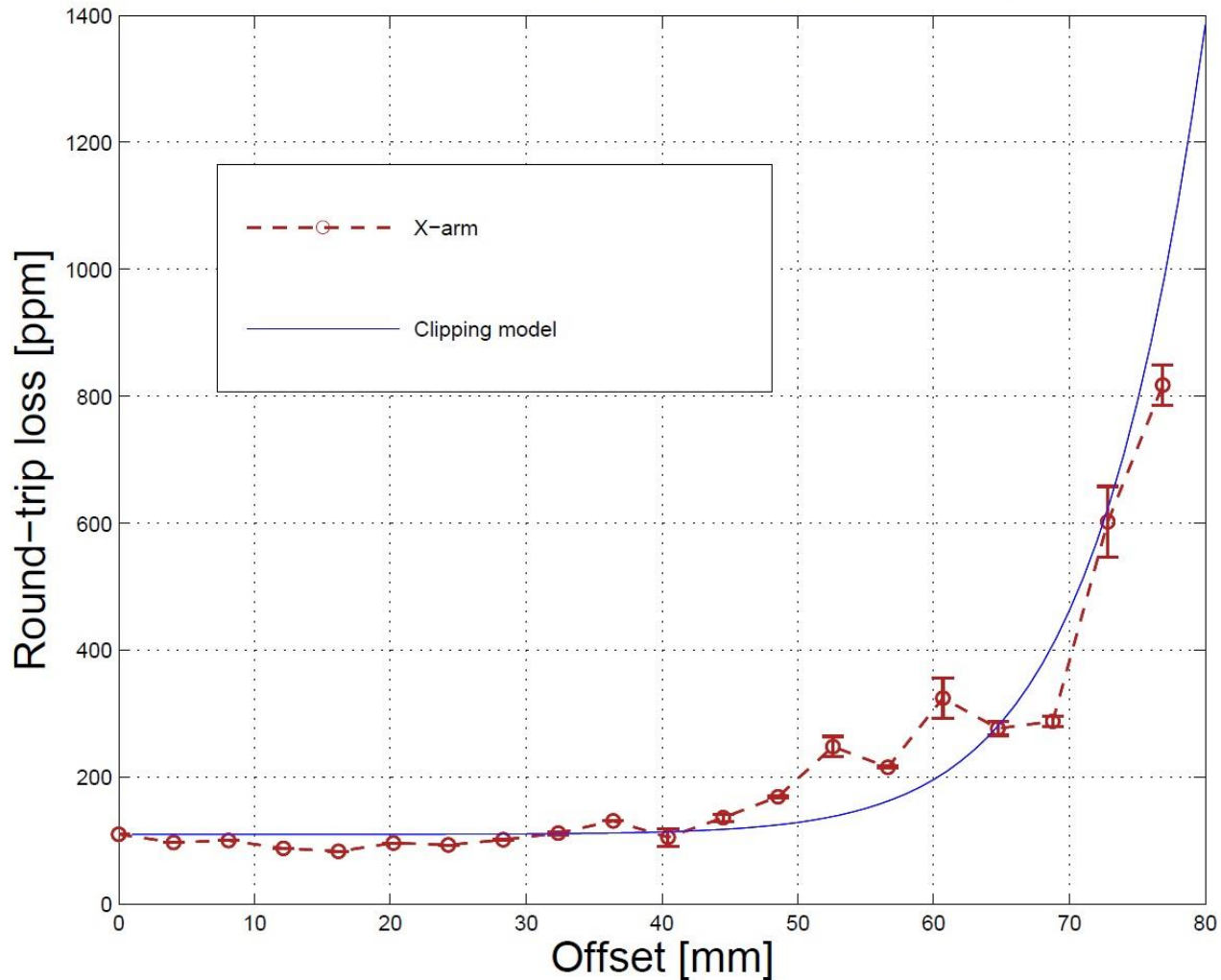
ITMY At 2014-08-16-05-11-01 UTC



Loss in each arm



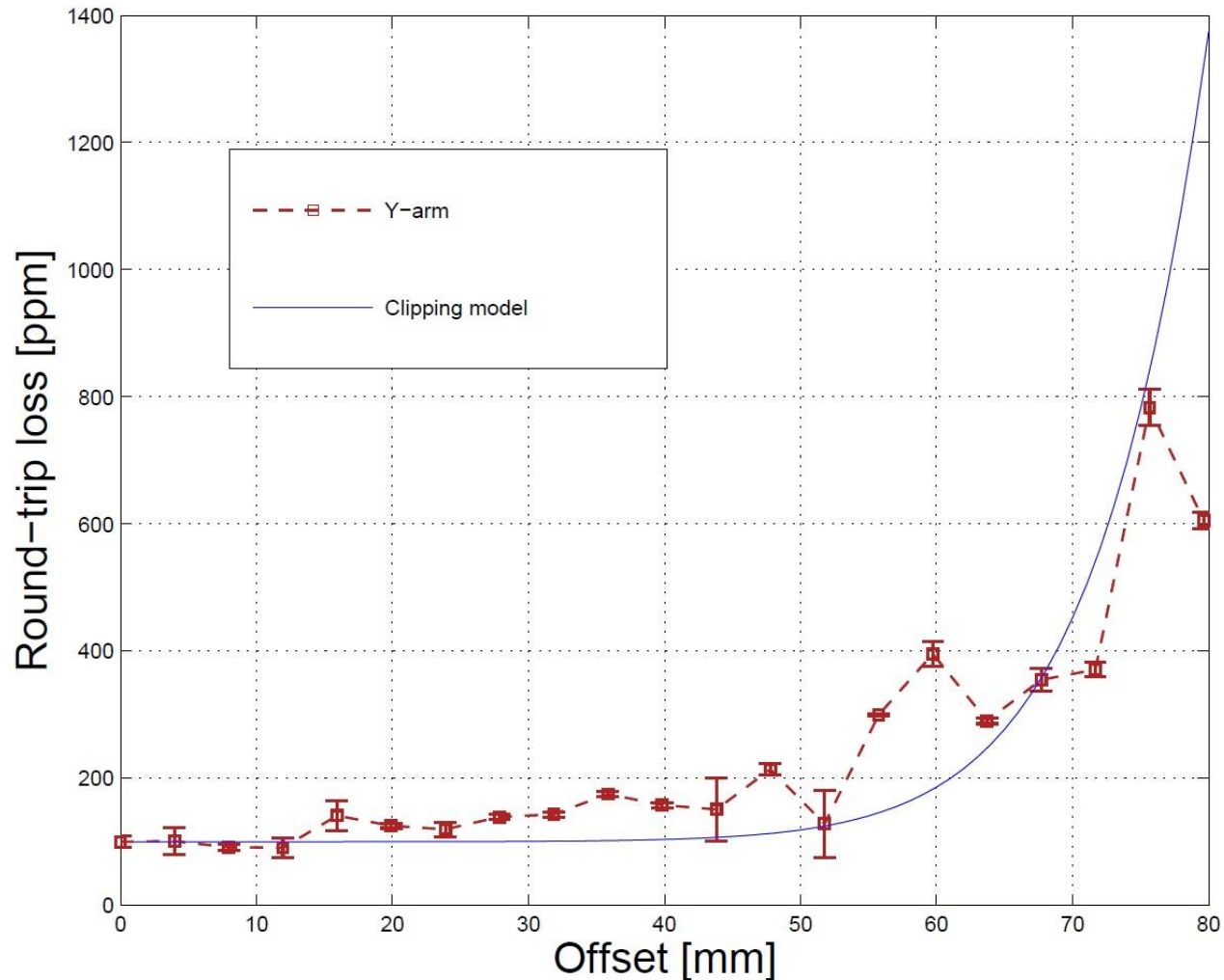
X-arm measurement & Model



Scattering loss ITMX:20ppm ETMX:50ppm

→ Where did the other 30 ppm come from?



Y-arm measurement & Model



Scattering loss ITMY: unknown ETMY:36ppm

→ ITMY scattering measurement is needed.

Summary

-  Loss dependence on off-centering of beam position
-  Estimated center position on each optics

Further prospects

- Statistical error

More measurement at each beam spot

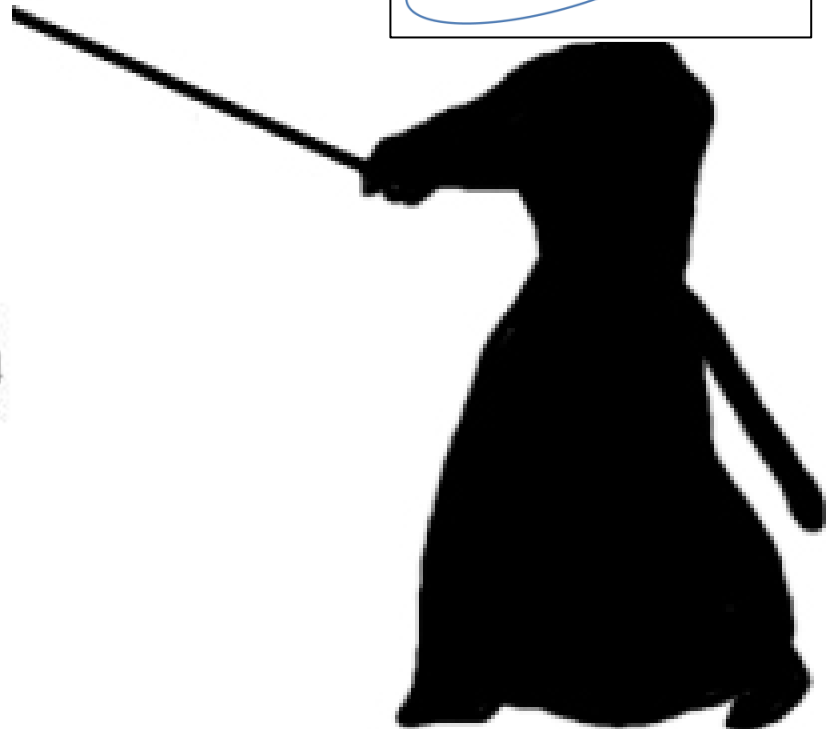
- 2-dimensional loss measurement

Measure on other directions from the center

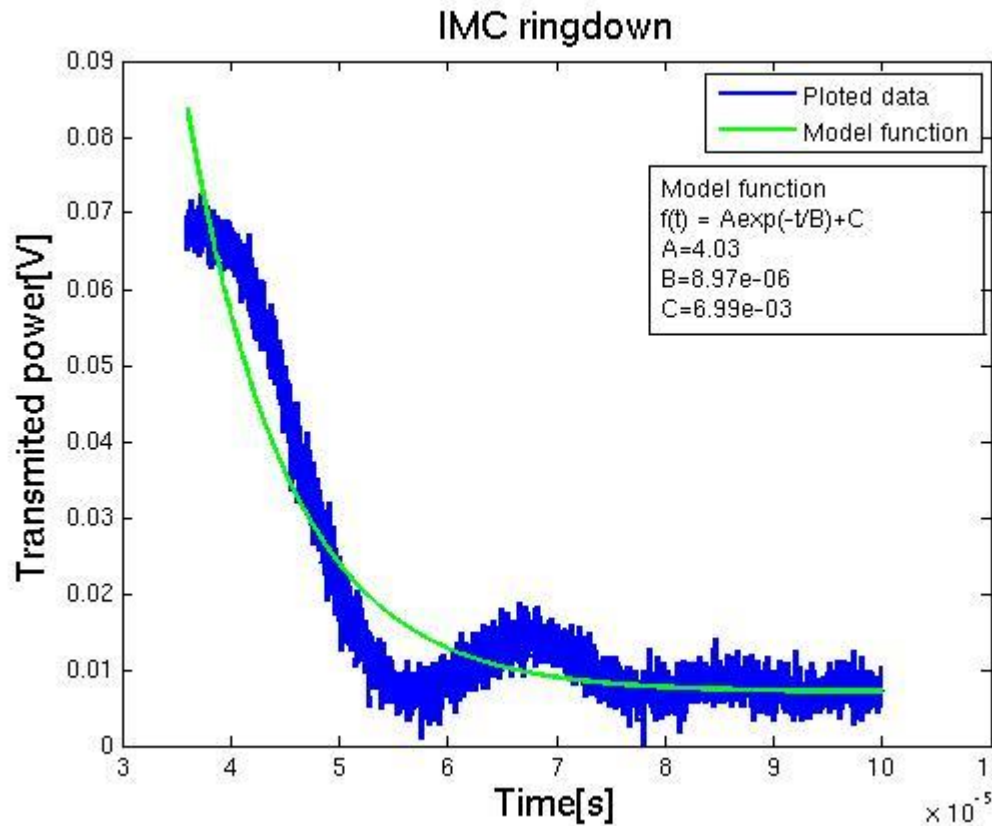
- Scattering error

ITMY!! Measure scatter from individual particles

Thank you for listening!



Time constant of IMC ringdown



Not clean ringdown



Quicker lock loss?

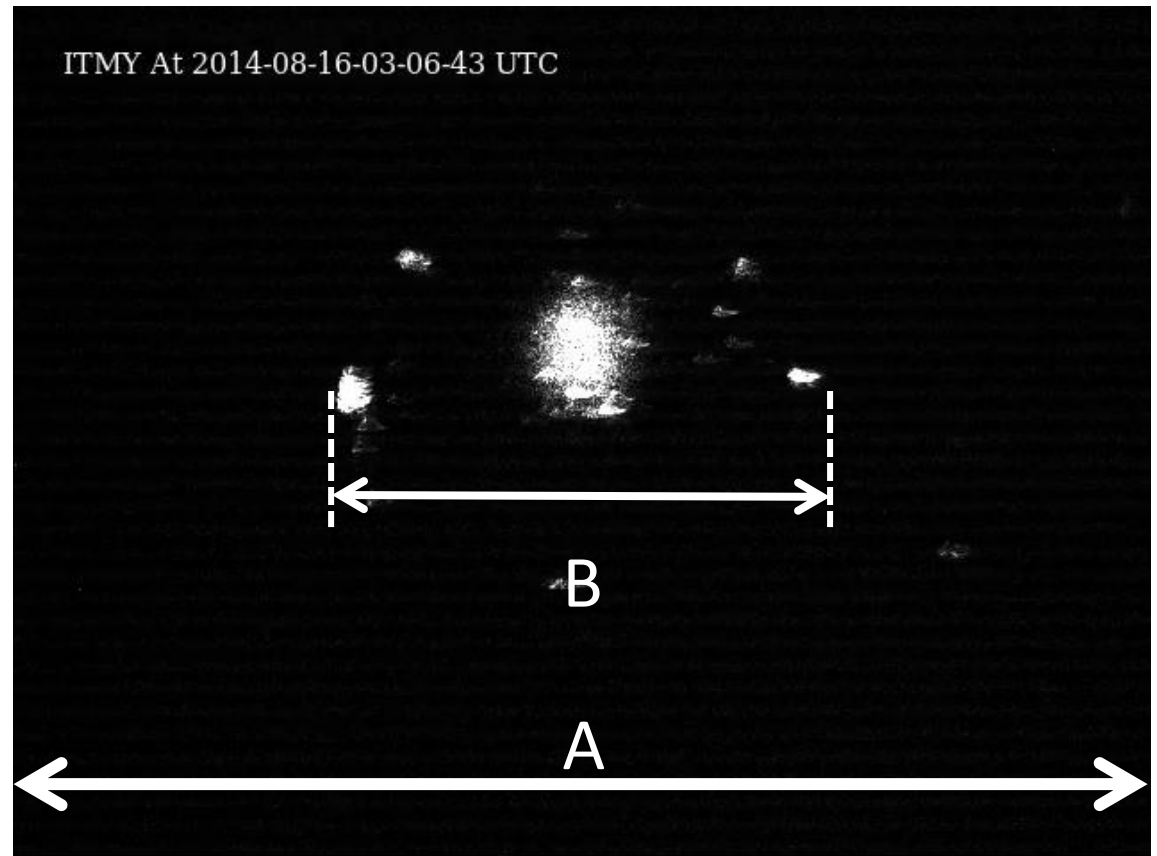
Mean [s]	Standard error [s]	Standard error per [%]
9.070×10^{-6}	3.0×10^{-8}	0.33

*Reference: 9.095×10^{-6} [s]

Camera calibration

← 640 pixels →

$$\frac{340[mm]}{640[pc] \times \frac{B}{A}} \\ \cong 0.53 \times \frac{A}{B} [mm/pc]$$



Ringdown method

$$m_1 = P_0 + P_1$$

$$m_2 = P_0 K T_i^2 R_e$$

$$m_3 = P_0 K [r_i - r_e (T_i + R_e)]^2 + P_1$$

$$m_4 = \tau$$

$$= \frac{L_{cavity} \times Finesse}{\pi c} = \frac{L_{cavity}}{c} \cdot \frac{\sqrt{r_1 r_2}}{1 - r_1 r_2}$$

$$(K = 1/(1 - r_1 r_2))^2)$$

$$* r_e = (1 - 5.0 \times 10^{-6}) \quad T_e = 5.0 \times 10^{-6}$$