Loss Dependence on Beam Position in the Arm Cavities of aLIGO

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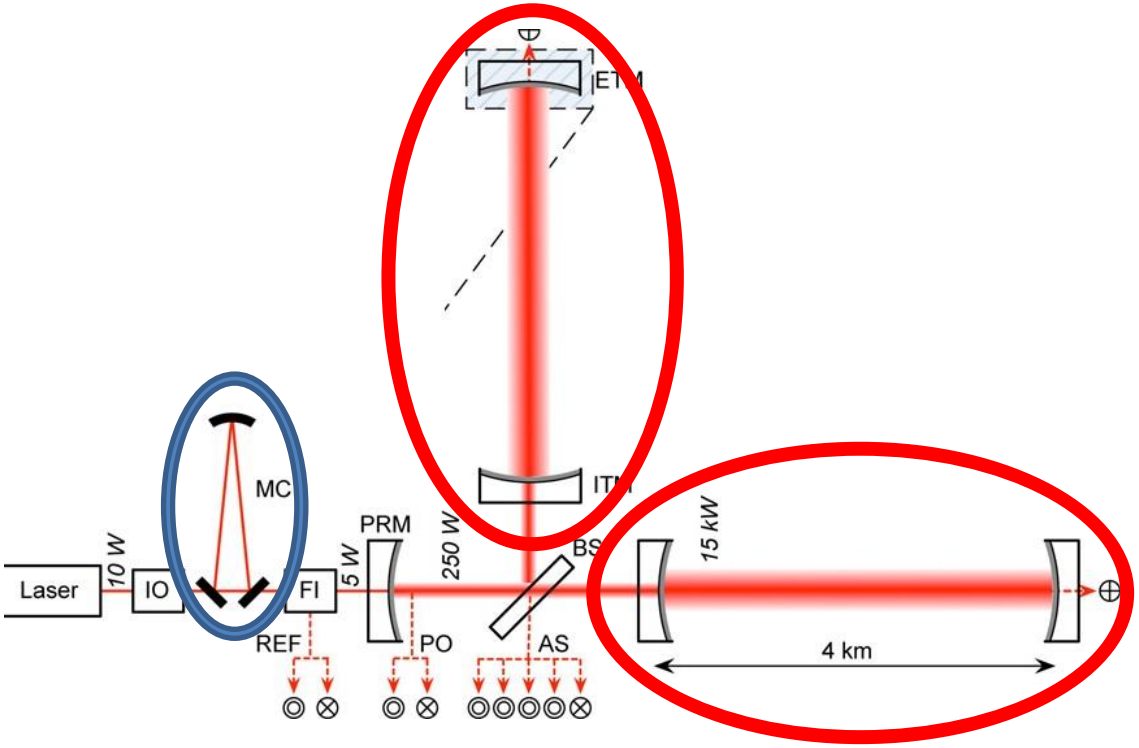
What did I do?

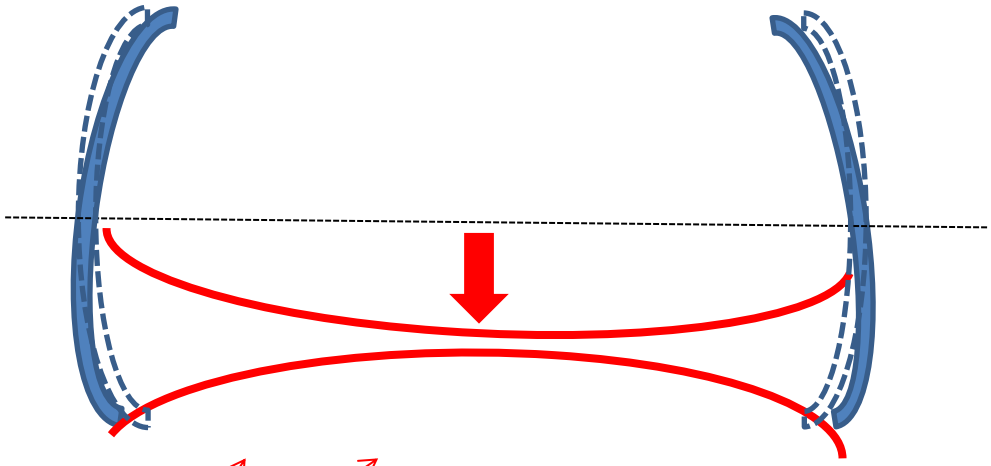
Optical loss in the 4km arm cavities

High cavity power → ○ High sensitivity!!

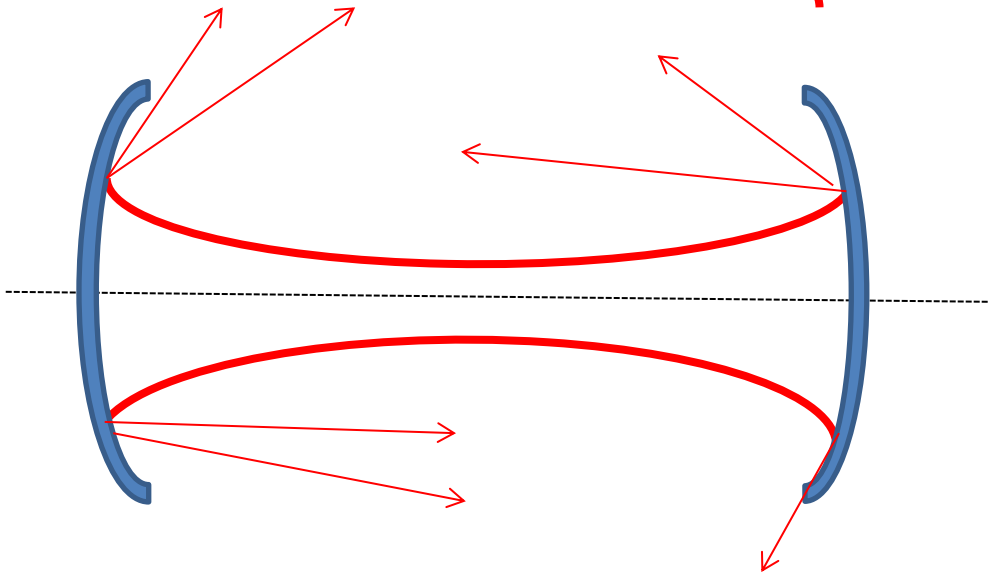


Where do the loss come from?

1 Geometrical loss

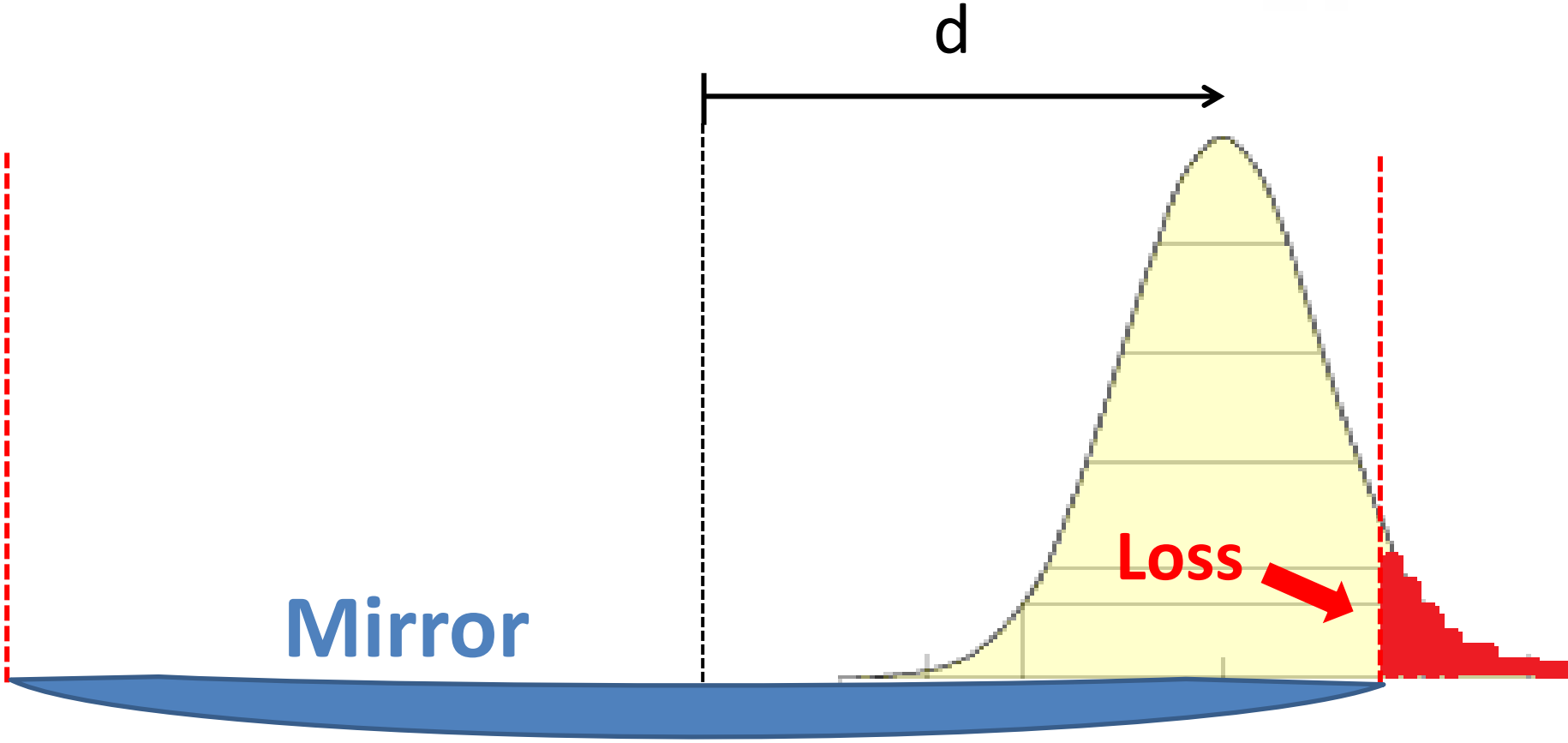


2 Scattering loss



Clipping model : Loss(d)

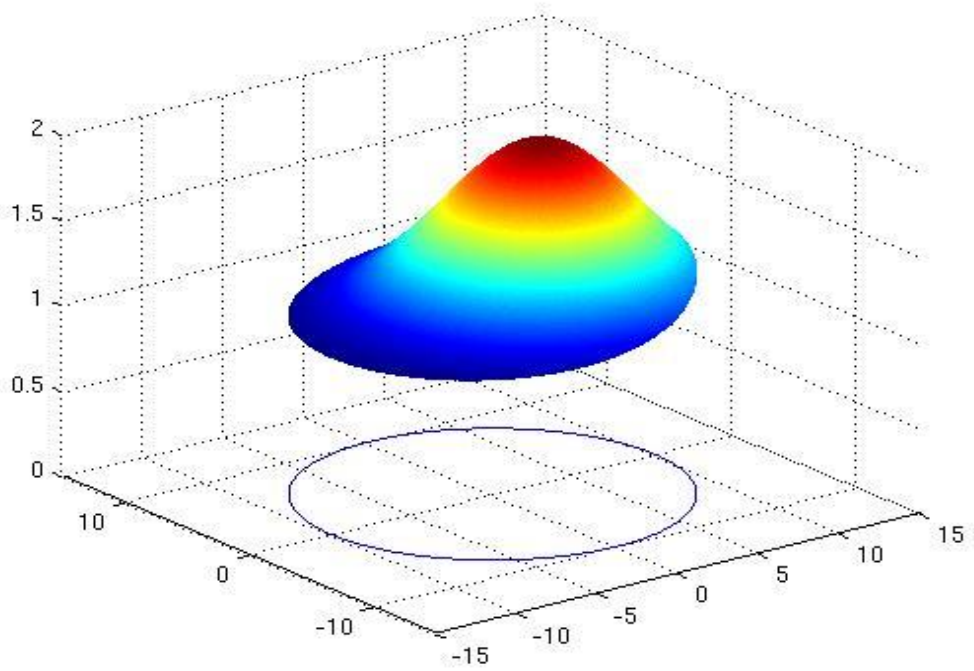
- TEM00 $u(x,y,z) = E_0 \frac{w_0}{w(z)} \exp\left\{ i[kz - \phi(z)] + \left(-\frac{1}{w^2(z)} + i\frac{k}{2R(z)} \right) r^2 \right\}$



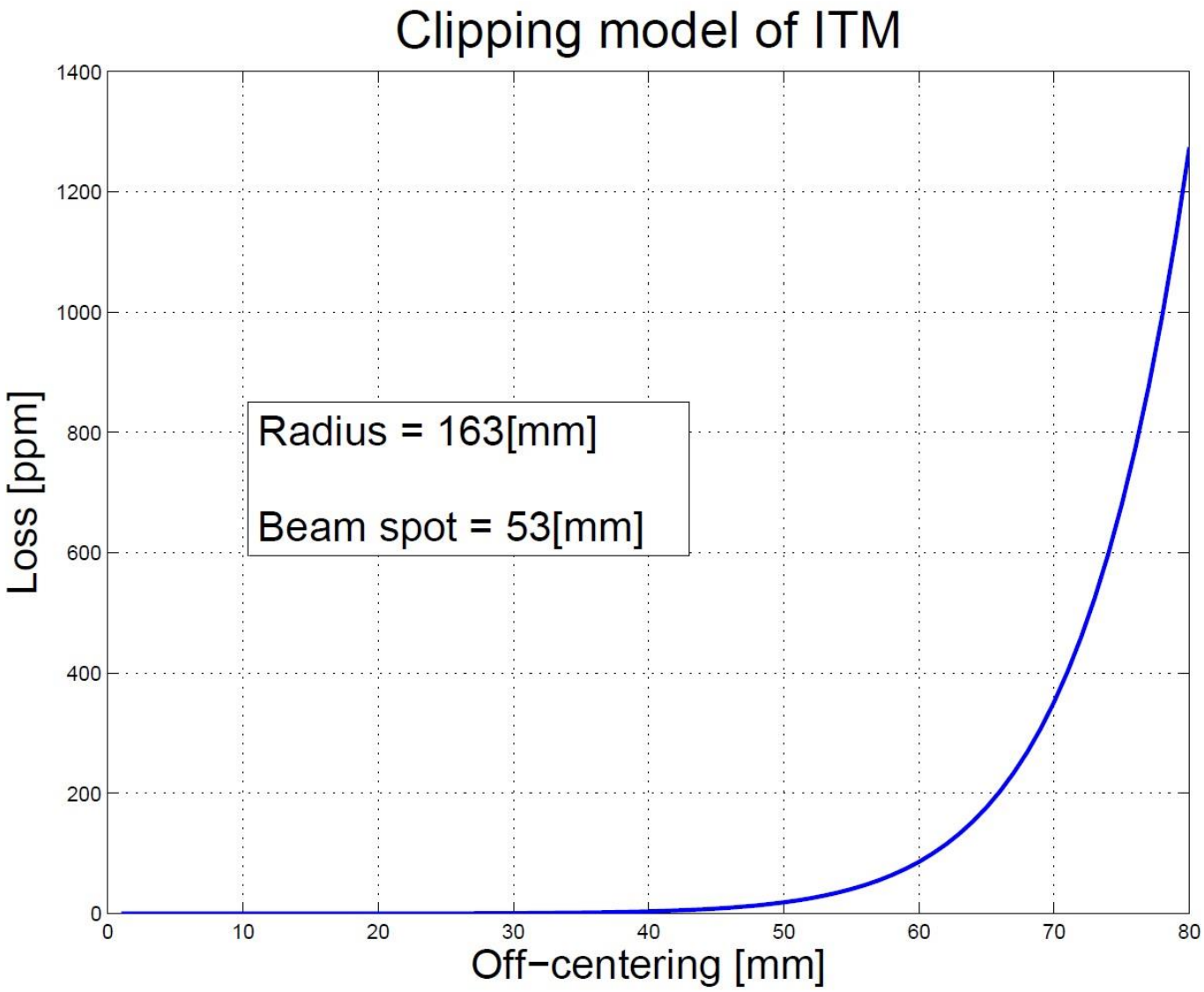
Clipping model : Loss(d)

$$L(d) = 1 - \frac{1}{N} \iint_D dxdy \; e^{-\frac{2}{w^2}\left((x-d)^2+y^2\right)} \quad st \quad D : x^2 + y^2 \leq R^2$$

$$= 1 - \frac{1}{N} \int_0^R dr \int_0^{2\pi} d\theta \; r \, e^{-\frac{2}{w^2}\left((rcos\theta-d)^2+(rsin\theta)^2\right)}$$

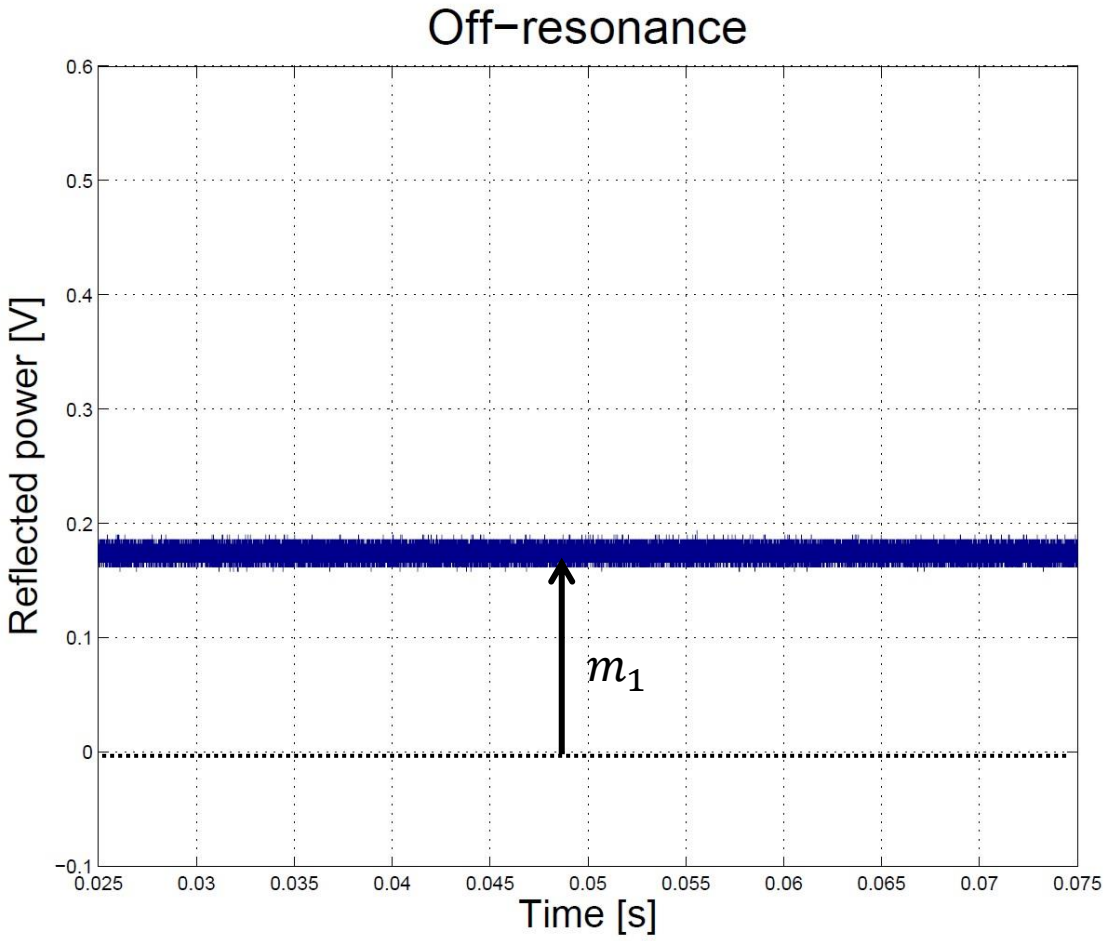


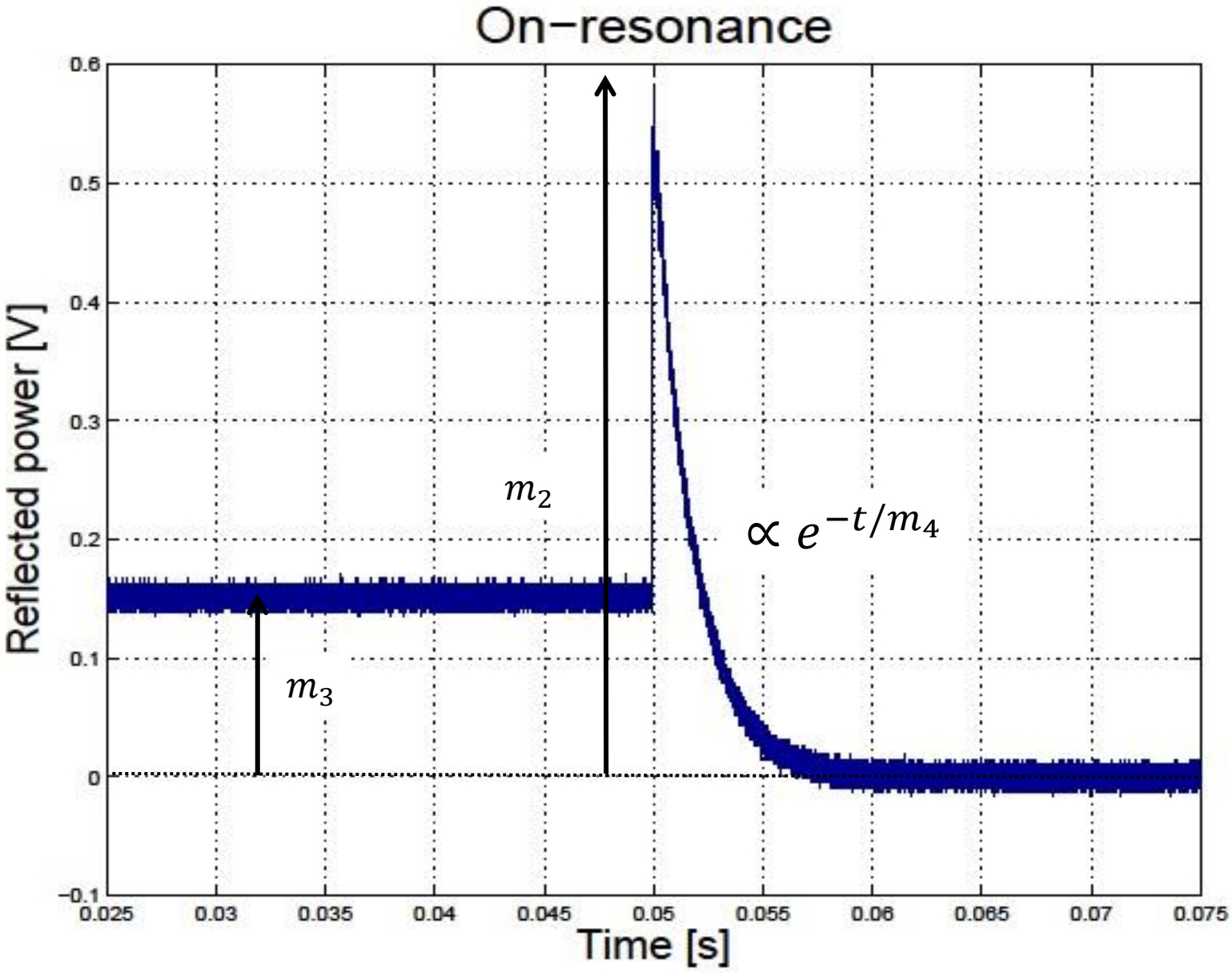
Simulation results

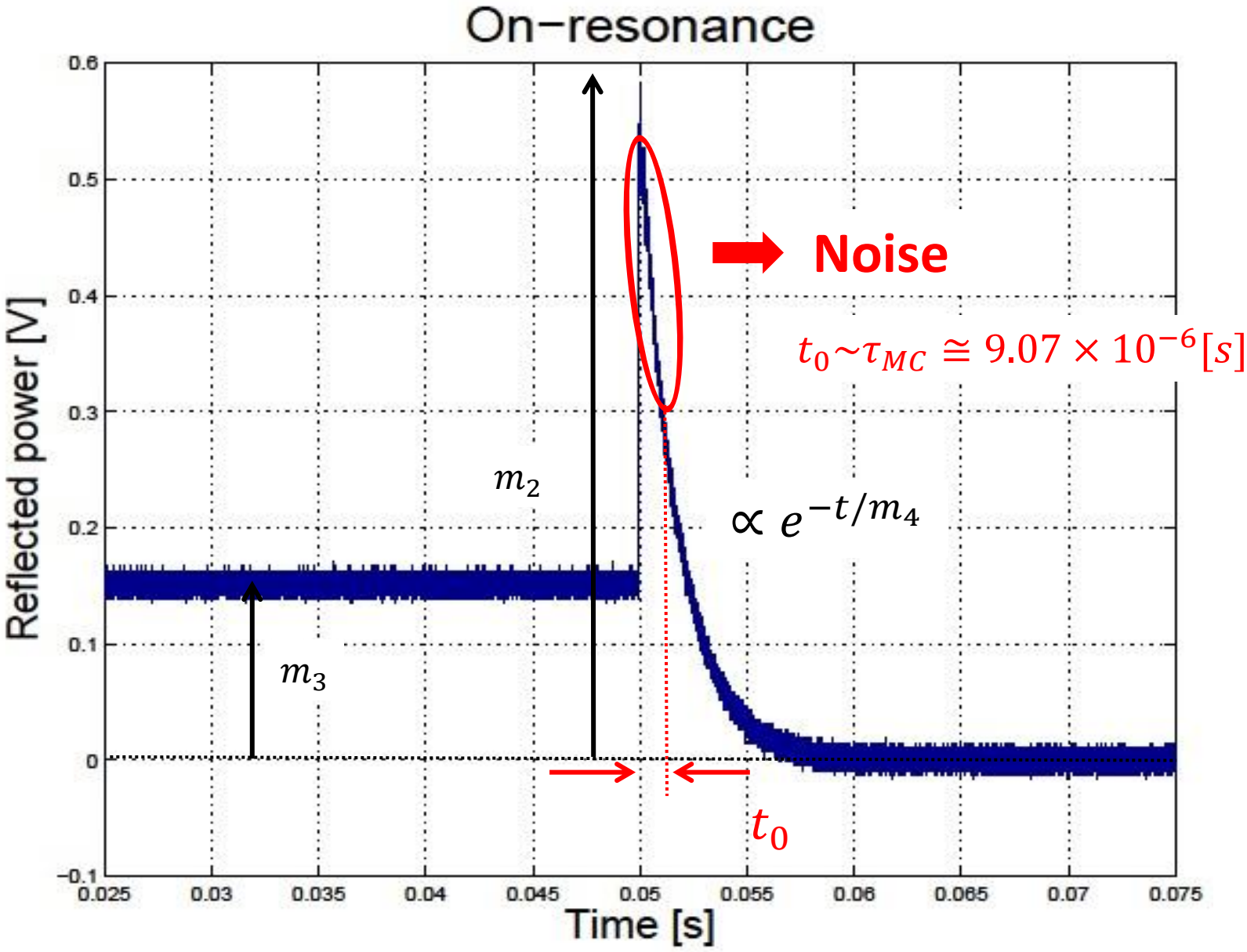


Experiment

- Ringdown method




On−resonance
Reflected power [V]
Time [s]
m_2
m_3
$\propto e^{-t/m_4}$
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
0.065
0.07
0.075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0.05
0.055
0.06
0.065
0.07
0.075
m_2
m_3
$\propto e^{-t/m_4}$
t_0
Noise
$t_0 \sim \tau_{MC} \cong 9.07 \times 10^{-6}[s]$

Ringdown method

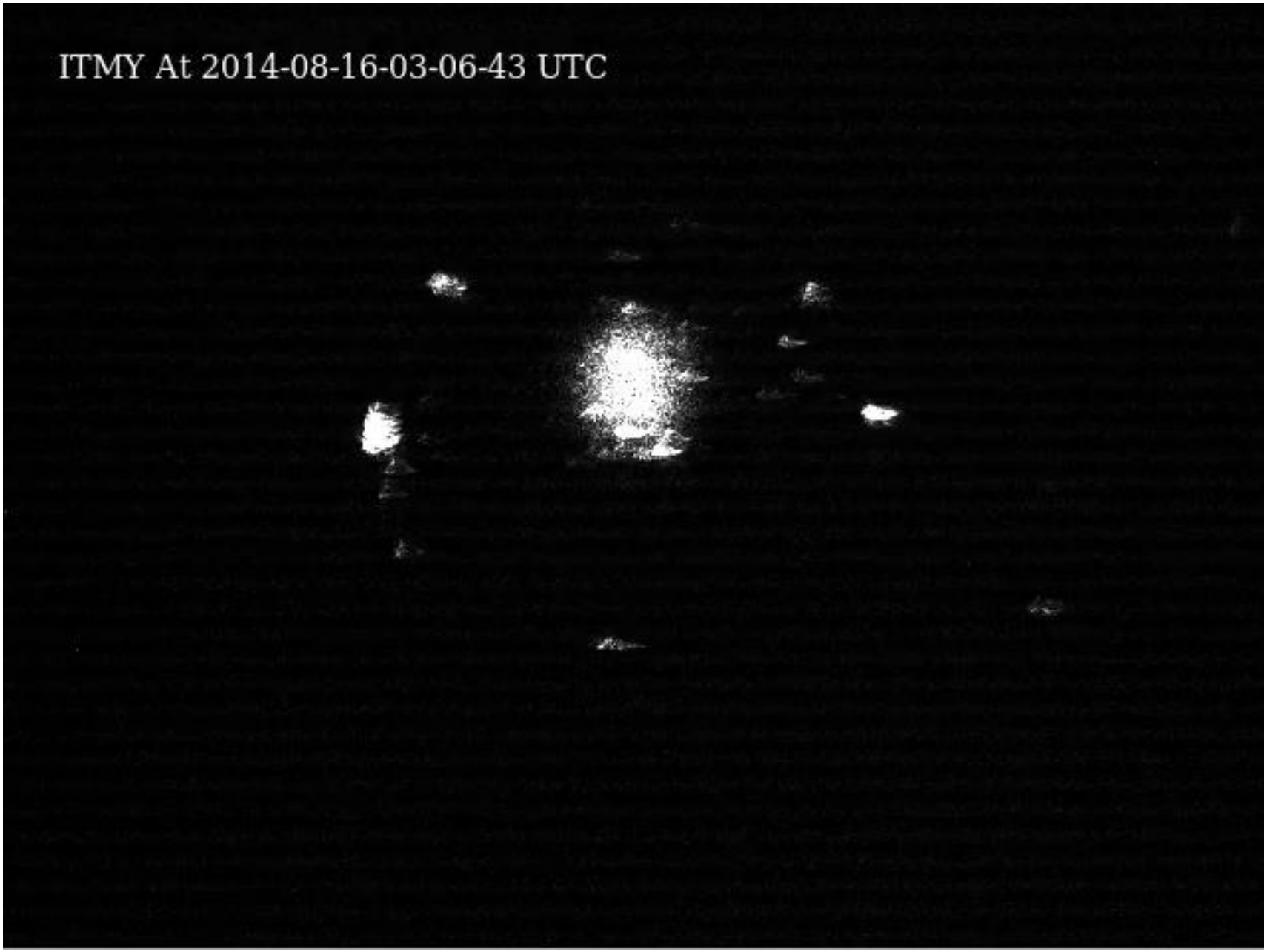
$$
\begin{aligned}
m_1 &= P_0 + P_1 \\
m_2 &= P_0 K T_i^2 R_e \\
m_3 &= P_0 K [r_i - r_e(T_i + R_e)]^2 + P_1 \\
m_4 &= \tau \\
&= \frac{L_{cavity} \times Finesse}{\pi c} = \frac{L_{cavity}}{c} \cdot \frac{\sqrt{r_1 r_2}}{1 - r_1 r_2} \\
(K &= 1/(1 - r_1 r_2)]^2)
\end{aligned}
$$

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

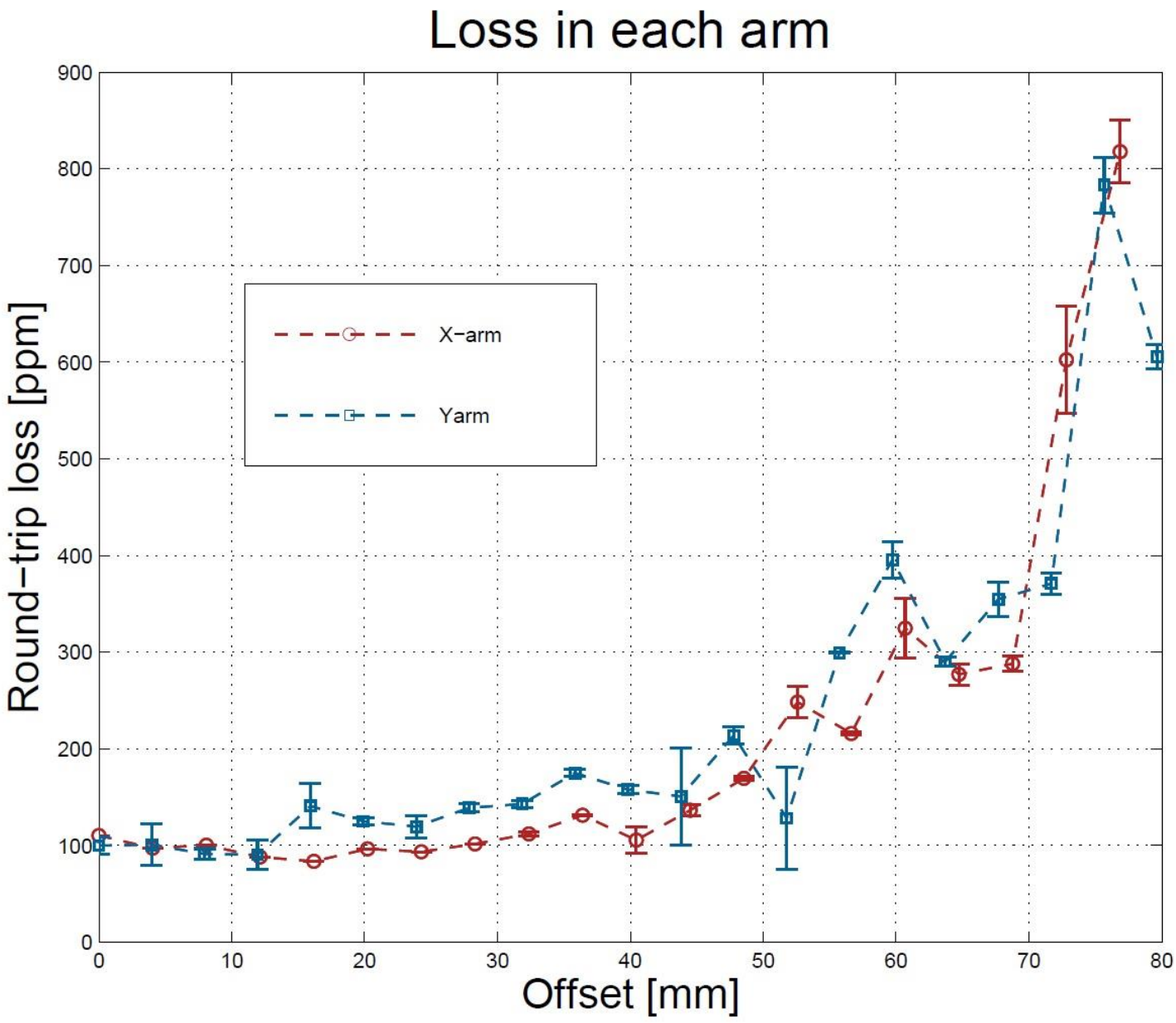
$$
m_1, m_2, m_3, m_4 \Rightarrow T_{ITM}, R_{ITM} \Rightarrow L_{rt} = 1 - T_{ITM} - R_{ITM}
$$

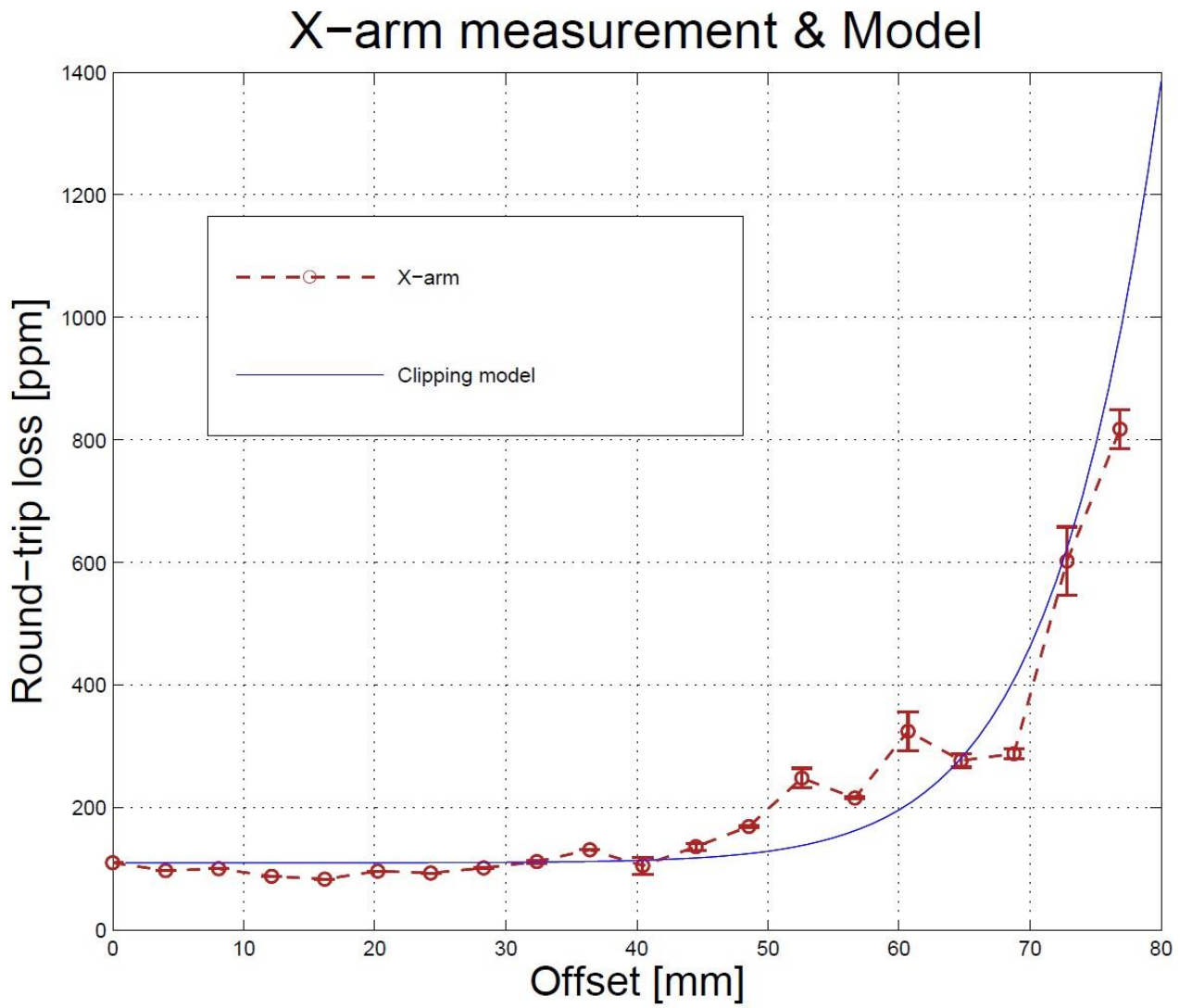
(cf. Isogai *et al*, Optical Express, Vol.21, No.24(2014))


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


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

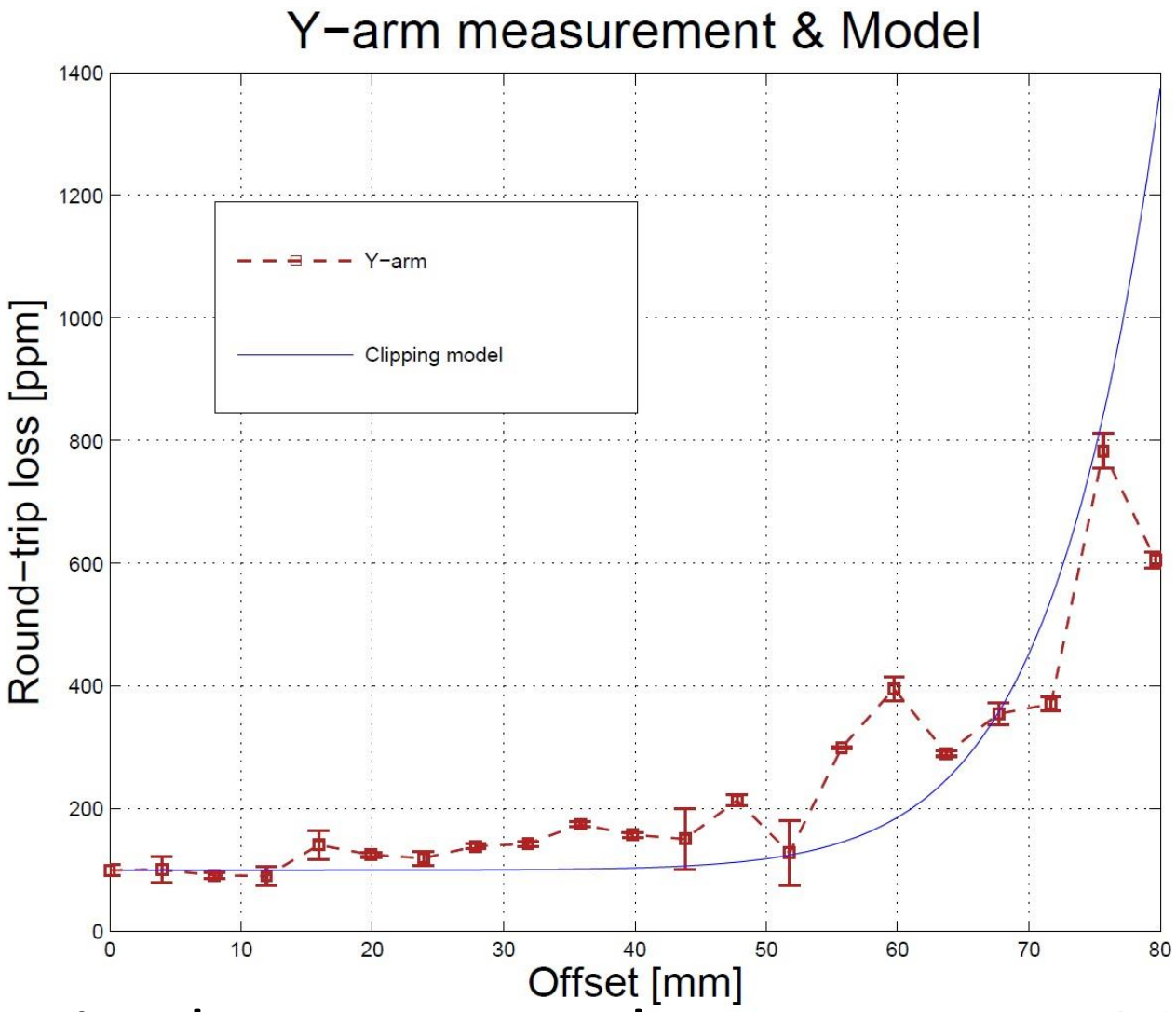

!TMY At 2014-08-16-05-11-01 UTC


Loss in each arm
Round−trip loss [ppm]
Offset [mm]
X−arm
Yarm
0
100
200
300
400
500
600
700
800
900
0
10
20
30
40
50
60
70
80



Scattering loss ITMX:20ppm ETMX:50ppm

→ Where did the other 30 ppm come from?



Scattering loss ITMY: unknown ETMY:36ppm

→ ITMY scattering measurement is needed.

Summary

- Loss dependence on off-centering of beam position

Further prospects

- Statistical error

  More measurement at each beam spot

- 2-dimensional loss measurement

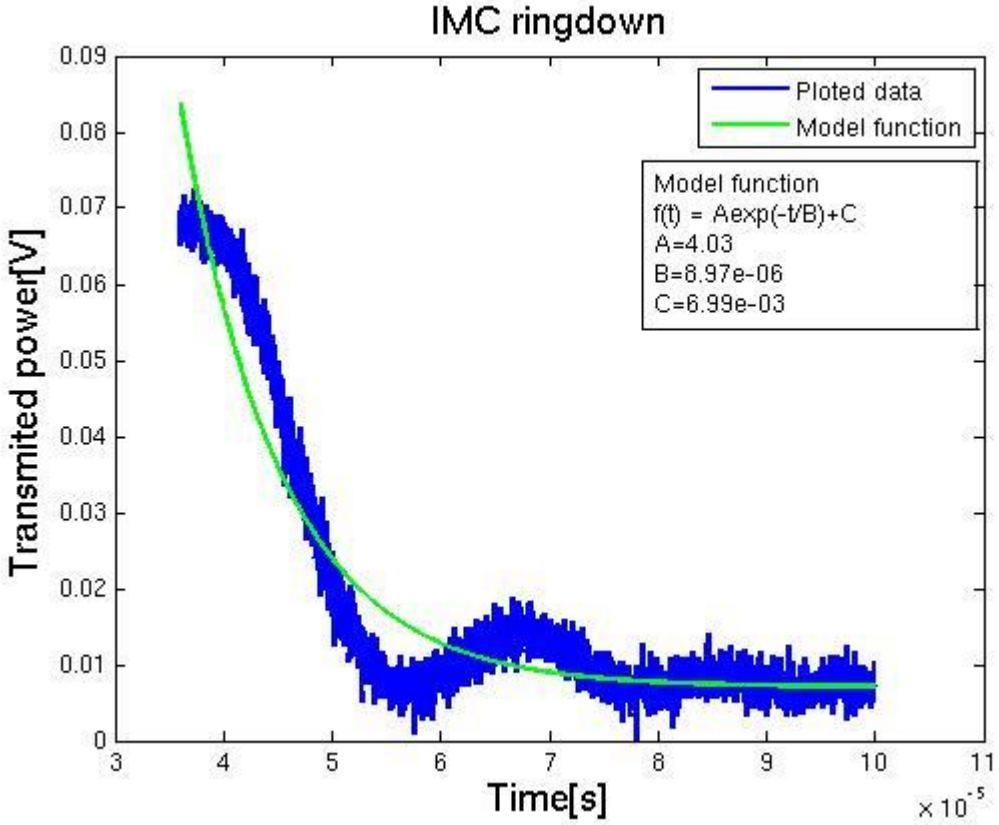
  Measure on other directions from the center

- Scattering error

  ITMY!!

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: $9.095 \times 10^{-6}[s]$

Camera calibration

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

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