① RIN

$$RIN = \frac{1}{1 + \left[2F\frac{x_0 + \delta x}{\lambda}\right]^2}$$

CORRECTED EXPRESSION

$$= 1 - \left[\frac{2F}{\lambda}\right]^2 x^2$$

$$= 1 - \left[\frac{2F}{\lambda}\right]^2 (x_0 + \delta x)^2$$

$$= 1 - \left[\frac{2F}{\lambda}\right]^2 x_0 \delta x \quad (*)$$

x_0 = displacement from resonance
δx = oscillation $A \sin \omega t$

$$RIN = \ldots - \left(\frac{2F}{\lambda}\right)^2 A \sin \omega t \cdot x_0$$

demodulate RIN · $\sin \omega t$

$$\text{error signal} = -\left(\frac{2F}{\lambda}\right)^2 \frac{A}{2} \cdot x_0$$

$$\left(\sin^2 \omega t = \frac{1 - \cos 2\omega t}{2}\right)$$

② PZT drive 0.23 V amplitude (peak)

$\rightarrow 2.6 \times 10^{-9}$ m

using calibration of 11.3×10^{-9} m/V

error signal calibration

$$\frac{\text{RIN demod}}{m} = 7.3 \times 10^{8} \ \frac{\text{RIN}}{m}$$

error signal RMS $= 4.7 \times 10^{-5}$ RIN

$\rightarrow 6.4 \times 10^{-14}$ m RMS

Residual RMS motion of OMC in Loop

6.4×10^{-14} m

(3) noise in DARM 7×10^{-21} m/$\sqrt{\text{Hz}}$ @ 100 Hz

optical gain 3.4×10^{6} cts/m
of LSC-DARM-IN

$$\frac{\text{DARM-IN}}{\text{OMC DCPD-NORM}} = 1.6 \times 10^{-5} \ \frac{\text{cts}}{\text{RIN}}$$

$$\text{opt. gain} = \frac{3.4 \times 10^{6} \ \text{cts/m}}{1.6 \times 10^{-5} \ \text{cts/RIN}} =$$

$$= 2.13 \times 10^{11} \ \frac{\text{RIN}}{m}$$

noise in DARM $\rightarrow$ RIN $= 1.5 \times 10^{-9}$ RIN/$\sqrt{\text{Hz}}$

④ From equation above (*)

$$RIN = \underbrace{\left(\frac{2F}{\lambda}\right)^2 \langle x_0 \rangle_{RMS}}_{3.6 \times 10^4 \ \frac{RIN}{m}} \cdot \delta x$$

$$\delta x = \frac{1.5 \times 10^{-9} \ RIN/\sqrt{Hz}}{3.5 \times 10^4 \ \frac{RIN}{m}} = 4 \times 10^{-14} \ m/\sqrt{Hz}$$

OML length noise equivalent to DARM excess noise

$$4 \times 10^{-14} \ m/\sqrt{Hz}$$