TNI Progress and Status: Ring Dampers and Aperiodic Coatings

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LSC Meeting

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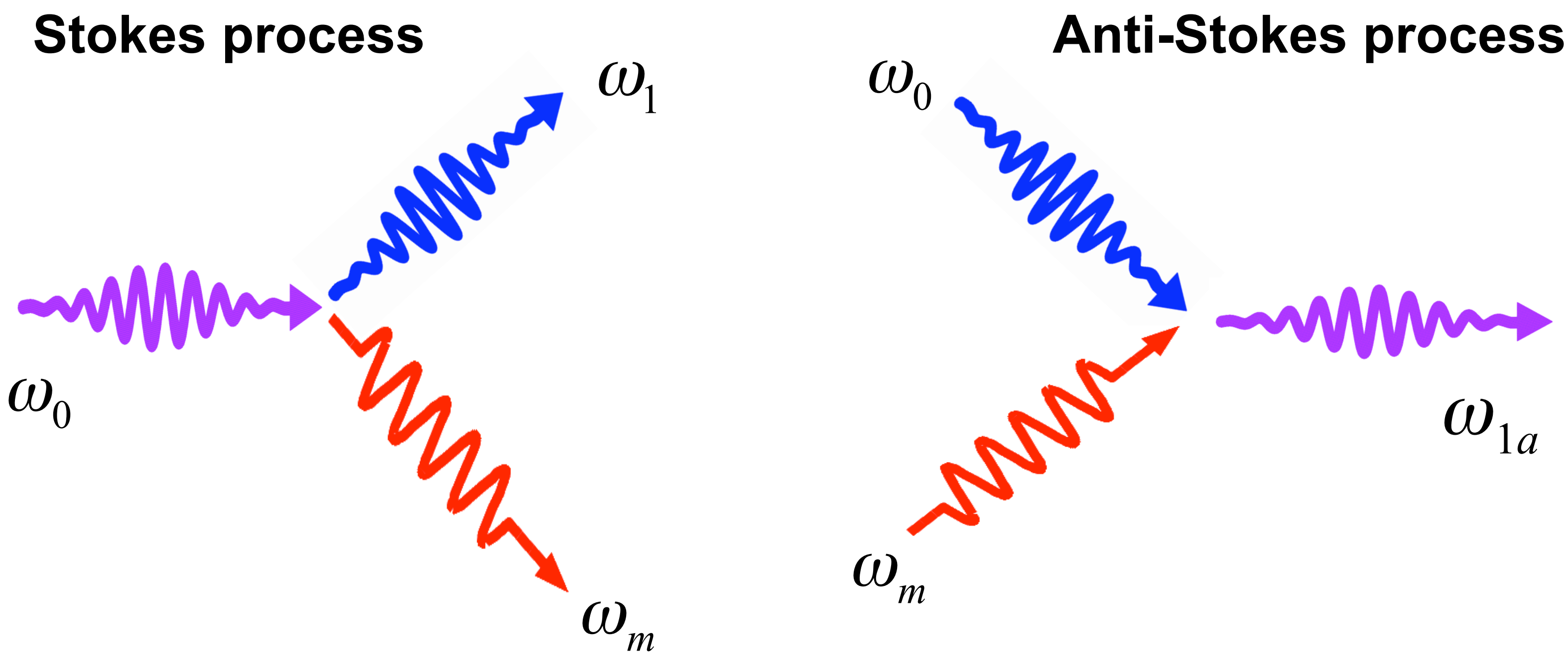
G060448-00-Z

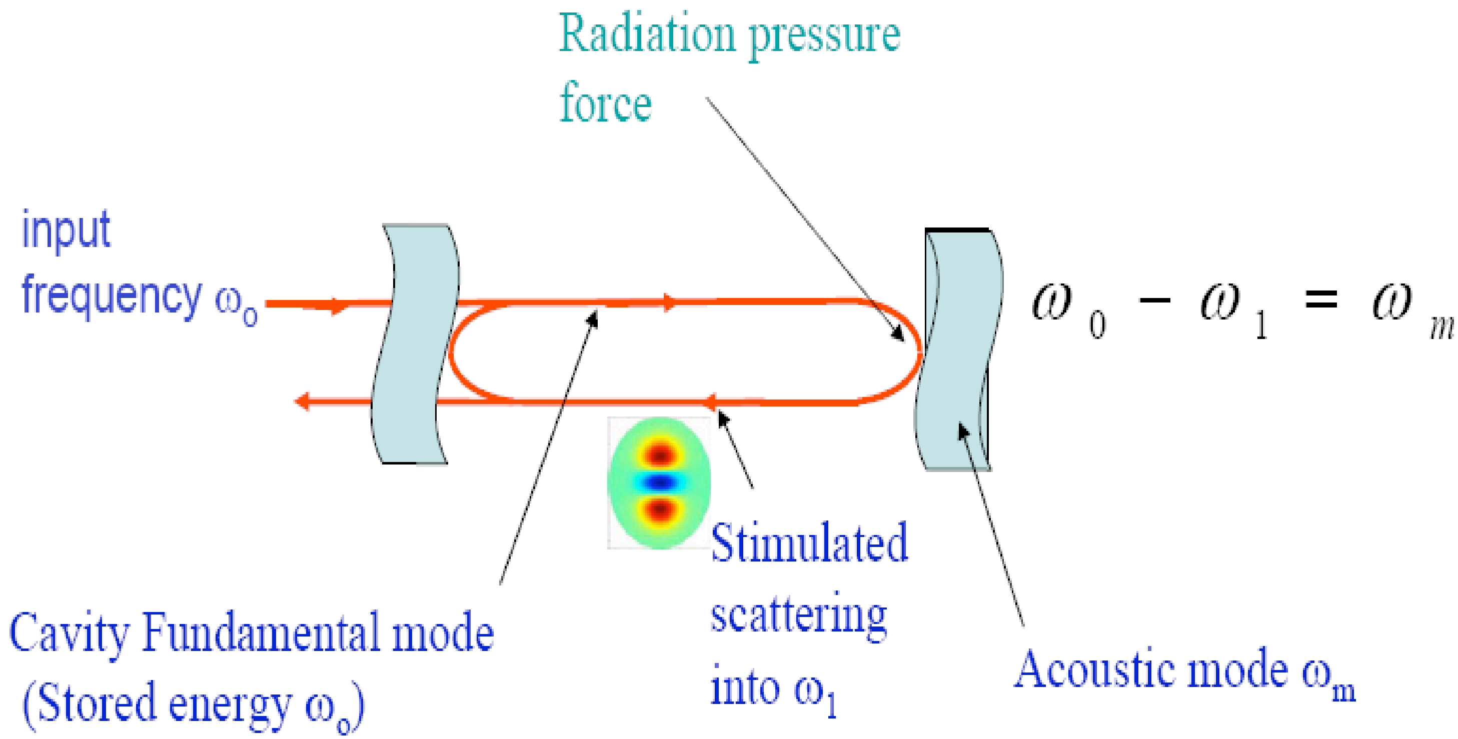
Acousto-Optic Coupling



$$\omega_1 = \omega_0 - \omega_m$$

$$\omega_{1a} = \omega_0 + \omega_m$$

Parametric Instability



Ju, et al. G050325-00

Condition for Instability

Mechanical Q

$$R \approx \frac{2PQ_m}{McL\omega_m^2}\left(\frac{Q_1\Lambda_1}{1+\Delta\omega_1^2/\delta_1^2} - \frac{Q_{1a}\Lambda_{1a}}{1+\Delta\omega_{1a}^2/\delta_{1a}^2}\right) > 1$$

Stokes Mode

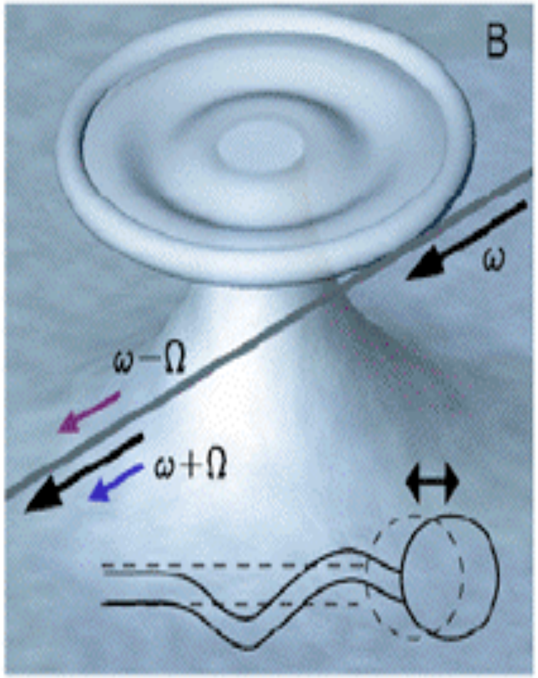
Anti-Stokes mode

Ju, et al. G050325-00 who got it from
Braginsky, et al. Phys. Lett. A 305, 111 (2002)

Experimental Verification

- Parametric *damping* (anti-Stokes) studied by Blair's group
  - PRL 74, 1908-1911 (1995).
- Effect observed in micro-cavities by Vahala group
  - Phys. Rev. Lett. 95, 033901 (2005)
- Also by Mavalvala in a suspended mirror cavity at MIT
  - LIGO-P050045-00-R (Oct. 27, 2005)

Microtoroidal optical resonator



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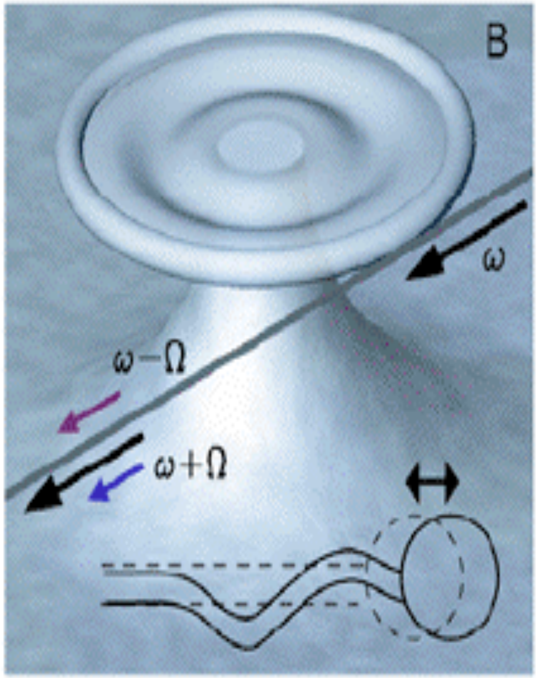


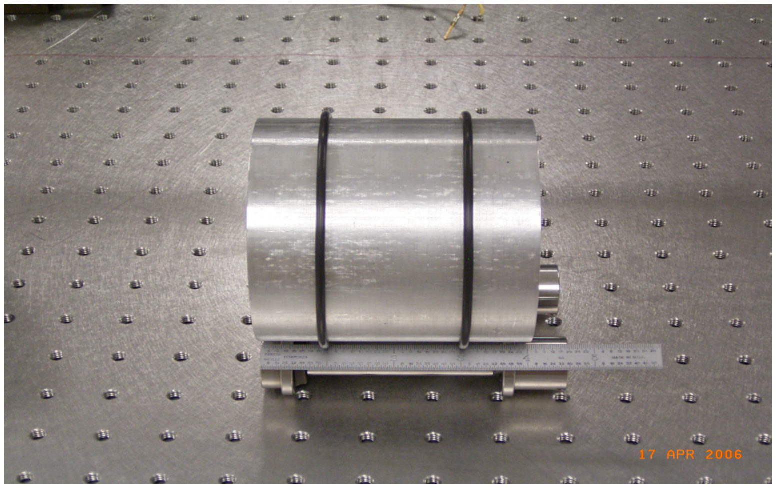
How do we eliminate parametric oscillations in AdLIGO without spoiling our low thermal noise floor?

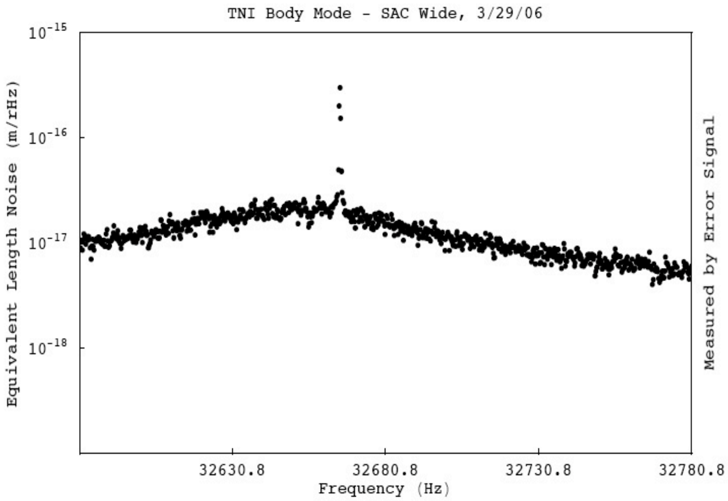
Possible Solutions

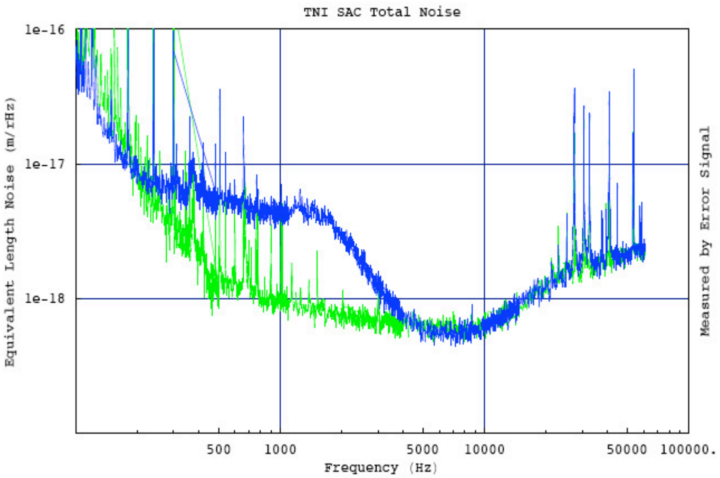
- Active feedback
- Thermal detuning
- Q reduction

Buna O-Rings

- Buna, 1/8” thick, undersized diameter (3.25”)
- Q reduction is too large to measure by ringdown: can’t excite modes
- Substantial increase in the noise floor from 200Hz to ~4kHz
- Still thermal noise limited above 5kHz







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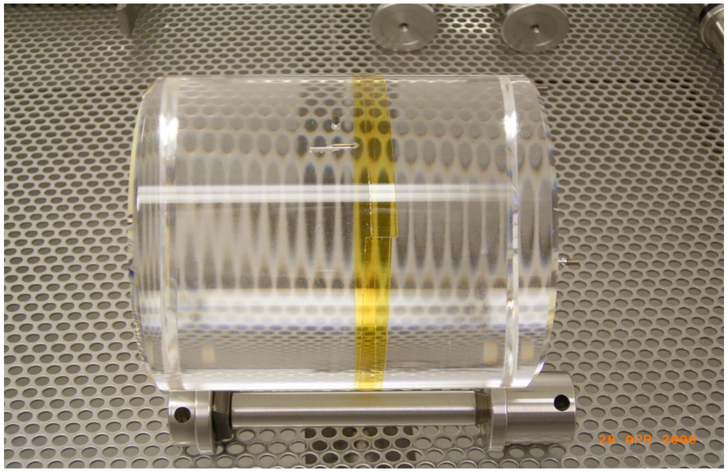
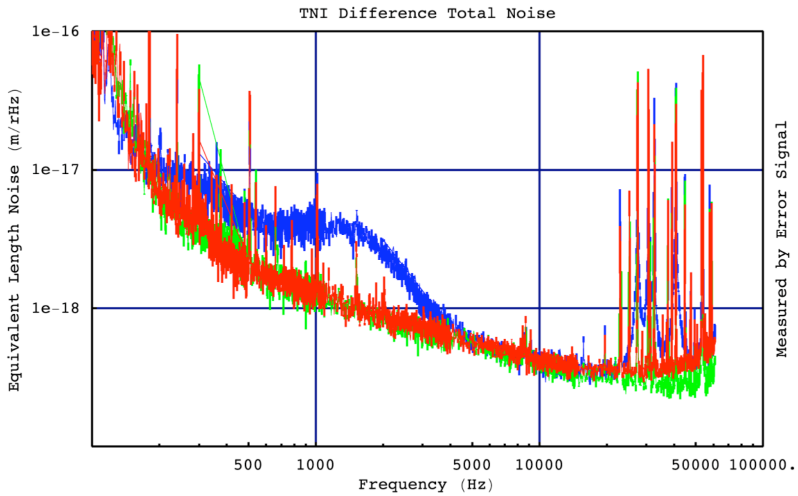
Kapton Tape

- Essentially massless, to avoid "waving" modes seen with buna.
- Lossy strip closely approximates models of Gras, Blair, et al.
- No observed increase in the noise floor
- Q reductions range from factor of 2 to none at all



No ring damper
Buna o-ring
Kapton tape



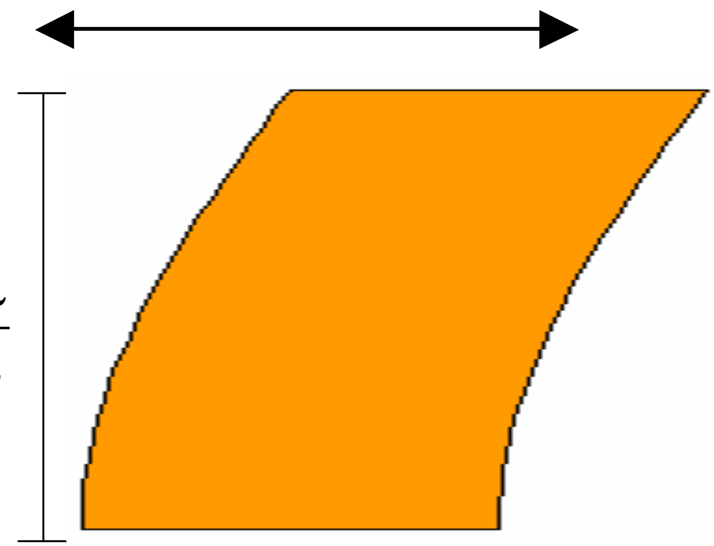
LIGO

“Waving” modes of rings

Shear wave equation (transverse waves)

$$\frac{\partial^2 y}{\partial x^2} = \frac{\rho}{G}\frac{\partial^2 y}{\partial t^2}$$

$$d = \frac{\lambda}{4}$$



→ wave speed $v = \sqrt{\frac{G}{\rho}}$

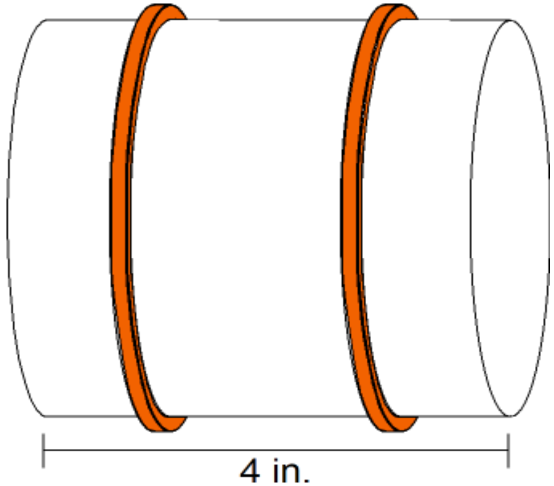
$$f_n = \frac{2n-1}{4d}\sqrt{\frac{G}{\rho}}$$

Predicts fundamental f = 145 kHz for 4 mm copper ring

- Well out of thermal noise region

Copper rings

- Buna, kapton results tell us
  - Need mass to damp mirror Q's
  - Need "waving" mode well above the measurement band
- Ultimate plan was to use monolithic rings, expanded by heating for installation
- Use screw tension for prototypes



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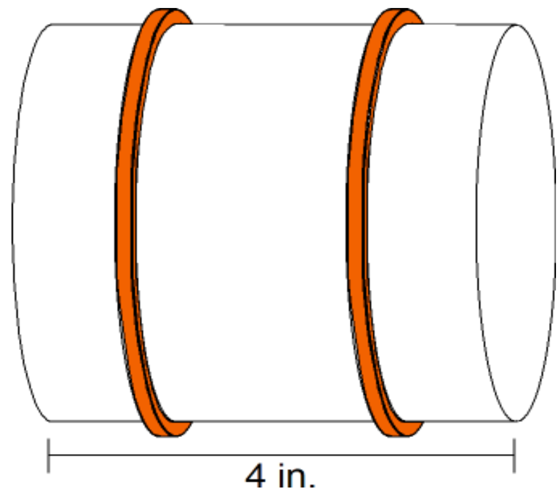

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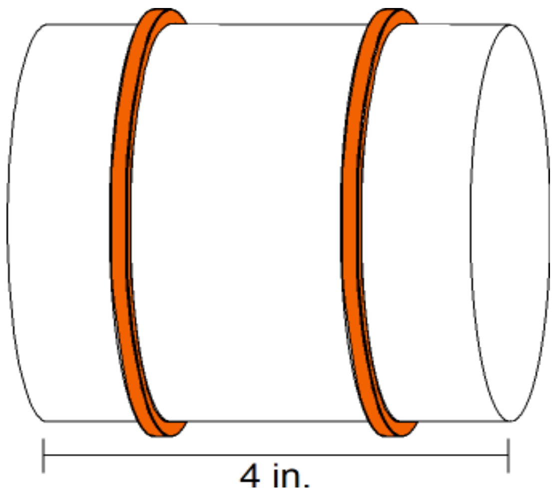
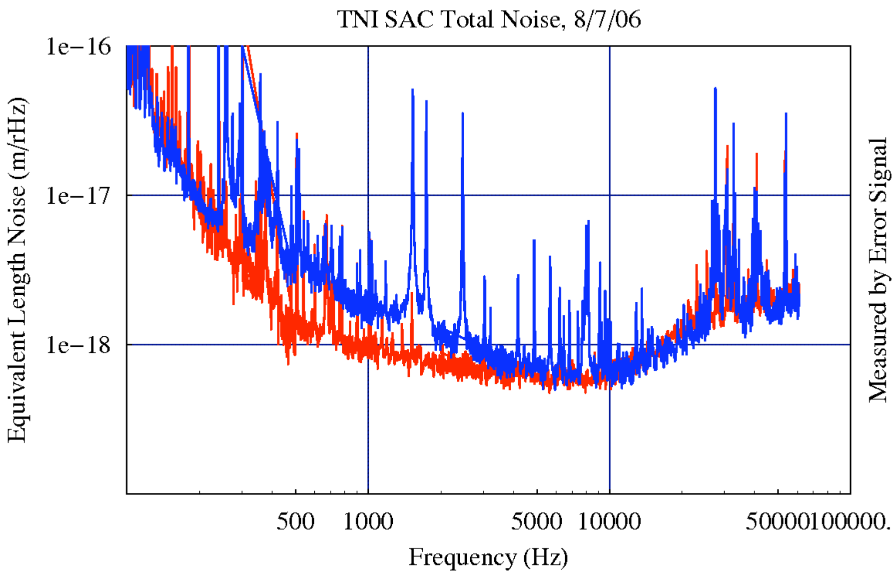
- Q's were reduced below our ability to excite the modes, as with buna.
- Noise floor increases, showing both new modes *and additional broadband noise*.





Aperiodic Coatings

- Goal: reduce high-loss material in HR coating by varying layer thickness, while preserving phase relationship for reflection
- Collaboration with
  - Vincenzo Galdi and Innocenzo Pinto at Benevento (coating design),
  - LMA at Lyon (fabrication and loss measurements), and
  - Sheila Rowan at Glasgow (loss measurements)
- Gains from and design of optimization depend on how different the loss angles are between high- and low-index materials.

$$1 \le \phi_{Ti-Ta_2O_5} / \phi_{SiO_2} \le 5$$

- We have well-confirmed measurements of $\phi_{Ti-Ta_2O_5}$, but not for ϕ_{SiO_2}
- Once we have a firm number for ϕ_{SiO_2} design can proceed.
- Once we have a design, LMA will fabricate a coating, and the TNI will measure its noise.