Discrete optics in optomechanical waveguide arrays: supplement

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In this section, we discuss how to obtain the stable optical field distribution and waveguide deflection using the iterative calculations in detail.

The time that the light passes through the waveguides is much shorter than the mechanical response time. We can presume that the optical response of this system is instantaneous. Initially, all of the waveguides are undeflected. Once the signal light is injected, an optical force distribution is given instantaneously. The optical force will deflect the waveguides a short moment later. Because the coupling coefficient $\kappa$ and the propagation constant $\beta$ are related with the vertical gap between suspended waveguides and the substrate, as shown in Eqs. (S1-S4), once the waveguide is deflected by the optical force, the coupling coefficient $\kappa$ and phase mismatching $\delta$ between the adjacent waveguides are changed, then the optical power distributions in the waveguides are changed, which will generate a new optical force distribution.

\[
\frac{dA_n(z)}{dz} = i\kappa_n(z)A_n(z)e^{-i\delta_n(z)} + i\kappa_{n-1}(z)A_{n-1}(z)e^{-i\delta_{n-1}(z)} \quad (S1)
\]

\[
f_n(g) = \frac{1}{c} \frac{\partial n_{\text{eff}}}{\partial g} \quad (S2)
\]

\[
EI \frac{d^2 u(z)}{dz^2} = f_n(g_0 - u(z))P(z) \quad (S3)
\]

\[
\kappa_{i,j}(z) = \xi(u(z)) \text{, } \delta_{i,j}(z) = \left(\beta_i(z) - \beta_j(z)\right)/2 \quad (S4)
\]

where the function $\kappa_n(z) = \xi(u(z))$ is shown in Fig. 2(d) in the main text. $\beta_i(z)$ is the propagation constant which is dependent on $n_{\text{eff}}$. The relation between $n_{\text{eff}}$ and $u(z)$ is shown as the red line in Fig. 2(b) in the main text. The optical power is $P(z) = |A(z)|^2$. The gap between the waveguide and the substrate is $g = g_0 - u(z)$, where $g_0$ is the initial gap.

Therefore, there is a feedback between the optical force and the optical power distribution. To calculate the final waveguide deflection, an iterative calculation has been done in this work. The calculation process is shown in Fig. S1. In the initial state, we can obtain the initial waveguide deflection of each waveguide, $u_n(z)$, where $m$ is the iteration number and the initial number is zero. Next, $\kappa_n(z)$, $\delta_n(z)$ can be obtained by Eq. (S4). Then, the optical field distribution $A_n(z)$ can be obtained by Eq. (S1) and the optical force can be calculated by Eq. (S2). Then, we can get a new waveguide deflection $u_{n+1}(z)$ by Eq. (S3). If $u_{n+1}(z) - u_n(z) > 10^{-12}$ m, we think the system doesn’t reach the stable state and continue to iterate. Otherwise, we think the waveguide have reached the stable state and stop the iteration. Finally, the stable optical field and the waveguide distribution can be obtained. When the signal power is 1.293
mW, the iterative calculation result is shown in Fig. S2. The horizontal-axis represents the iteration number and the vertical-axis represents the maximum deflection of the 9th waveguide. We can see that the waveguide reaches the stable state after 170 iterations.

Fig. S1 The flow chart of the iterative calculation.
Fig. S2 The iterative calculation result, when the signal power is 1.293 mW.