

# Two-mode waveguide with nonlinear ring resonator

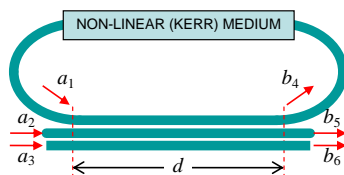
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We investigate theoretically and numerically the properties of a system made of a two-mode waveguide (WG) coupled to a single-mode nonlinear (Kerr) ring resonator (RR) of total length  $L$  [Fig. 1]. Time dependence is taken as  $\exp(+i \omega t)$ .



**Fig. 1. Schematic representation of the system in terms of scattering parameters, with the two-mode waveguide formally described as two coupled single-mode waveguides.**

The two-mode lower WG being formally equivalent to two coupled single-mode WGs<sup>[1]</sup>, the coupling zone of length  $d$  is well described by a  $(3 \times 3)$  matrix of the form:

$$\begin{pmatrix} b_4 \\ b_5 \\ b_6 \end{pmatrix} = \begin{pmatrix} \rho & -i \kappa & X \\ -i \kappa & \tau & -i \kappa' \\ X & -i \kappa' & \rho' \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix}, \quad (1)$$

with scattering parameters easily derived from coupled-mode theory<sup>[2]</sup>. Closing the loop with  $a_1 = b_4 e^{-i \beta (L-d)}$  (where  $\beta$  is the propagation constant), then reversing to the even ( $e$ ) and odd ( $o$ ) supermode basis, we obtain not only the  $(2 \times 2)$  Jones-like matrix of the system, but also the internal fields in the RR. For instance,  $b_4$  reads:

$$b_4 = a_e \frac{\sqrt{2}}{2} \left( \frac{X - i \kappa}{1 - R e^{-i \phi}} \right) + a_o \frac{\sqrt{2}}{2} \left( \frac{X + i \kappa}{1 - R e^{-i \phi}} \right), \quad (2)$$

where  $R e^{-i \phi} = \rho e^{-i \beta (L-d)}$ , and  $a_e$  (resp.  $a_o$ ) denotes the amplitude of the *even* (resp. *odd*) input mode. Both modes are equally coupled into the RR and contribute to the nonlinear effect. With  $\phi = \phi_{in} + 2 \pi (|b_4|^2 / P_K)$  the total phase, where  $P_K$  is the Kerr power of reference, a self-consistent calculation enables one to determine the internal state, thus the bistability domain. Moreover, the system can work as a nonlinear mode mixer.

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## References

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