Chapter 66
Modal Behaviour and Switching Properties of a Tailored Parity-Time (PT) Symmetric Grating

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Abstract We analyse the diffraction behaviour of a parity-time (PT) symmetric transmission grating. This kind of grating consists of a periodic structure with balanced real and imaginary parts of the refractive index. The bimodal interferometric operation (Mach-Zehnder like) is modified by the introduction of balanced gain and loss, leading to efficient switching around an exceptional point.

Usually we try to avoid loss in optics, because it limits the efficiencies of many applications. However, the concept of PT symmetry (originating from quantum mechanics [1, 2]) allows for a proper use of loss, when it is judiciously balanced with gain. The main property of PT symmetric devices is that they switch from what is called a unbroken phase to a broken phase through an exceptional point. This effect is really suited for switching applications. PT symmetry already facilitated various interesting and counter-intuitive phenomena, such as optical Bloch oscillations and loss induced lasing.

We numerically analyse a diffraction grating (Fig. 66.1a) that was extensively discussed without loss/gain in [3]. This grating is tailored to achieve very high diffraction efficiencies. By introducing gain and loss (quantified by γ) in the grating we can now find out its rich transmission characteristics.

We identify two different regimes [4], which are adjusted by the not-often studied longitudinal feedback (see Fig. 66.1b) for the direct transmission T_0). The properties are explained by the two Bloch modes in the grating. Below an exceptional point ($\gamma = 0.23$) the grating acts like a Mach-Zehnder interferometer, with a gain-controlled coupling length. Beyond this point there is one mode with gain (due to symmetry breaking), which provides us with lasing resonances.

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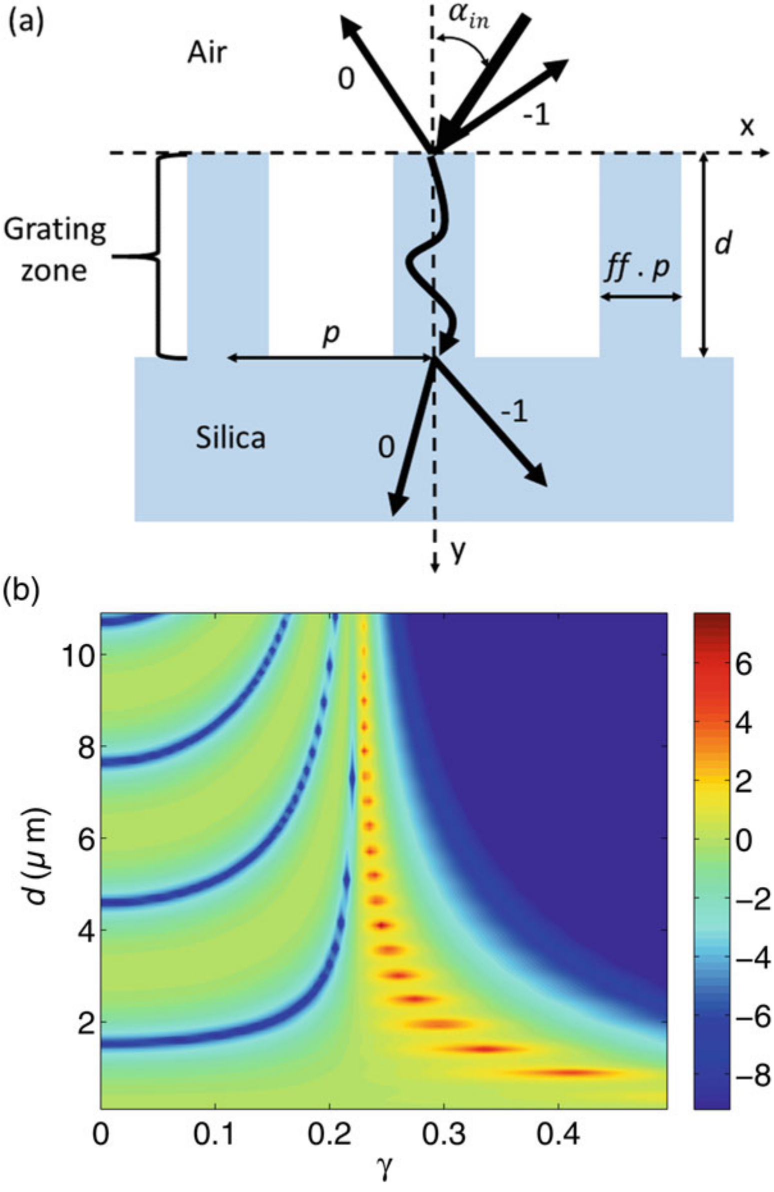

Fig. 66.1 **(a)** Diffraction grating with the reflection and transmission orders. **(b)** Transmitted light (log scale) to T_0 as a function of groove depth d and gain/loss factor γ

References

1. Bender, C. M., & Boettcher, S. (1998). Real spectra in non-Hermitian Hamiltonians having PT symmetry. *Physical Review Letters, 80*, 5243.
2. Bender, C. M. (2007). Making sense of non-Hermitian Hamiltonians. *Reports on Progress in Physics, 70*, 947.
3. Clausnitzer, T., Kämpfe, T., Kley, E.-B., Tünnermann, A., Peschel, U., Tishchenko, A. V., et al. (2005). An intelligible explanation of highly-efficient diffracion in deep dielectric rectangular transmission gratings. *Optics Express, 13*, 10448.
4. Rivolta, N. X. A., & Maes, B. (2015). Diffractive switching by interference in a tailored PT-symmetric grating. *Journal of the Optical Society of America B, 32*, 1330.