The prospect of judiciously utilizing both optical gain and loss has been recently suggested as a means to control the flow of light. This proposition makes use of some newly developed concepts based on non-Hermiticity and parity-time (PT) symmetry ideas first conceived within quantum field theories. By harnessing such notions, recent works indicate that novel synthetic structures and devices with counter-intuitive properties can be realized, potentially enabling new possibilities in the field of optics and integrated photonics. Non-Hermitian degeneracies, also known as exceptional points (EPs), have also emerged as a new paradigm for engineering the response of optical systems. Such non-Hermitian degeneracies are by themselves interesting entities. As opposed to standard degeneracies, at an EP, not only do the eigenvalues coalesce but so do the corresponding eigenstates. In fact, at such bifurcations, the relevant eigenvectors collapse on each other and as a result, the dimensionality of the system is abruptly reduced. This in turn has a profound effect on how the system responds to a perturbation. In this case one can show that when a perturbation of strength \( \varepsilon \) acts on an \( N \)-th order EP (when \( N \) eigenvalues and eigenvectors merge), the resulting eigenvalue (frequency) splitting is now proportional to \( \varepsilon^{1/N} \). This indicates that the sensitivity of a set-up can be enhanced by several orders of magnitude by exploiting the physics of EPs. Among many different non-conservative photonic configurations, parity-time (PT) symmetric arrangements are of particular interest since they provide an excellent platform to explore the physics of EPs for enhanced sensing applications. The enhanced response experimentally observed in a PT-ternary sensing system is shown in Fig. 1.

Another intriguing property of EPs is the way they respond if the system parameters vary in such a way so as to either enclose or not enclose such points. If the contour does encircle an EP in a quasi-static fashion, one can then show that the eigenvalues swap with each other and as a result, the eigenvectors follow suit. What makes this possible is the structure of the Riemann sheets in the complex domain upon which the eigenvalues move (Fig. 2). The situation is entirely different under dynamic conditions. If the parameters (coupling, detuning, birefringence etc.) of a two-level non-Hermitian system are dynamically varied in a judicious manner, in such a way that the contour enclosing the exceptional point follows a clockwise path, then only one of the local eigenvectors will appear at the output while the other eigenstate will be drastically suppressed. This adiabatic arrangement can faithfully convert any arbitrary mixture of states into one of the local states with a nearly unity transmission coefficient.

In this talk, we provide an overview of recent developments in this field. The use of other type symmetries in photonics will be also discussed.