Non-reciprocal propagation versus non-reciprocal control

To the Editor — A recent article[1] reports a nonlinear, non-reciprocal device and its application to isolation and routing of signals. Towards the end, the article clearly specifies that the device enables non-reciprocal propagation only for the forward and backward signals that are not coincident in time[2]. When the signals are coincident, the transmission is fully reciprocal and no isolation takes place. Nevertheless, the accompanying News and Views article[3] bears the title no less than 'Low-loss nonlinear optical isolators in silicon', and although the body of the article contains a statement about the aforementioned limitation, the device is referred to as an 'isolator' throughout the article. This, in my view, is not very helpful to readers, especially casual ones who may get an impression that an optical isolator has been developed, and this impression cannot be further from the truth.

As many nonlinear 'isolator' schemes have proliferated, the issue of 'What is — and what is not — an optical isolator' has been addressed in the namesake Commentary article[4] stating: "It is insufficient to find a state in which power can be transmitted from one side to the other and another state in which the power is not transmitted in the reverse direction. For a device to be an isolator it must block or divert all possible states for backward propagation." The nonlinear scheme[1] and its predecessors[5] can all be generically rendered as a sequence of an optical amplifier, a nonlinear switching element and an attenuator compensating the gain as shown in Fig. 1. Clearly the forward signal gets first amplified (or concentrated) and is capable of turning the switch to the ON state, while the backward signal is first attenuated and in the absence of a forward signal the switch remains in the OFF state. But whether the switch is in the ON or OFF state at a given time, it is in the same state for both forward and backward signals, that is, the scheme is fully reciprocal in terms of signal propagation. It is only non-reciprocal in terms of controllability from two sides. It is clearly not an optical isolator, and, in my opinion, a proper name for it should be a 'non-reciprocally-controlled' device. In such a device the forward signal equitably controls the propagation of both the forward and backward signals, while the backward signal controls propagation of neither one.

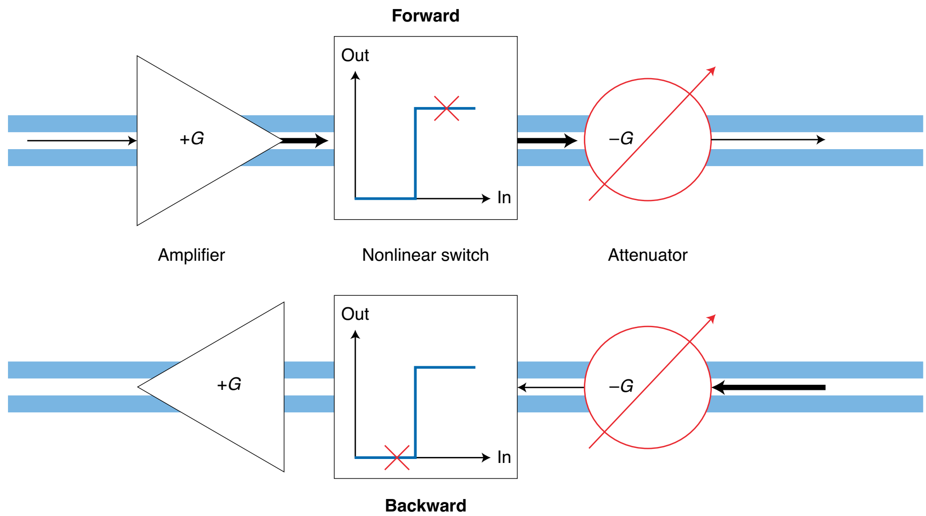

Fig. 1 | Explanation of a non-reciprocally-controlled device and why it's not an optical isolator. Generic representation of asymmetric nonlinear devices as a sequence of an optical amplifier with gain G (dB), a nonlinear optical switch and an optical attenuator with attenuation $-G$ (dB). The forward-propagating signal gets amplified, triggers the nonlinear switch into the ON state (shown by the cross) and then gets attenuated to the original input level. The backward-propagating signal first gets attenuated and thus cannot trigger the switch, which remains in the OFF state. But if the backward signal arrives concurrently with the forward signal, it finds the switch in the ON state and upon passing through the switch will get restored to its original level by the amplifier. At every moment, whether the switch is in the ON or OFF state, the light propagation is fully reciprocal.

To avoid further confusion, it should be noted that although the nonlinear scheme[1] as well as its many progenitors all fail to meet strict criteria for being an optical isolator, it does not mean that a true optical isolator cannot be built using nonlinear optics, for example, by frequency conversion[6].

In conclusion, while the non-reciprocally-controlled device is not an optical isolator it is still a very important accomplishment that demonstrates the greatly improved capabilities of nanophotonic design and fabrication, and will certainly find applications in enabling other existing and yet-to-be conceived functionalities of silicon-compatible active nanophotonic circuits. ❒

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Competing interests

The author declares no competing interests.