Solitons in semiconductor microcavities

To the Editor — In a recent Article published in *Nature Photonics*[1], Sich *et al.* reported the observation of bright polariton solitons in a semiconductor microcavity. As part of their analysis, the authors discussed the response time of polariton solitons in comparison with the response time of what they called "light-only solitons in semiconductor cavity lasers" or "pure-light cavity solitons in wide-aperture semiconductor lasers", citing work of Barland *et al.*[2], Pedaci *et al.*[3] and Ackemann *et al.*[4]

In this correspondence, we want to remark that the cavity solitons studied by Barland *et al.*[2] and Pedaci *et al.*[3], and reviewed by Ackemann *et al.*[4], are actually composite structures consisting intrinsically of both a light and a material component, and that referring to them as 'pure light' is therefore not appropriate.

Indeed, there is of course no nonlinear optics without a medium and any modulation of the light field will have a counterpart in terms of material variables, be it electronic states, Zeeman states, twist angles of liquid-crystal directors, carrier populations or coherences. Depending on the relative timescales involved, the material dynamics might be adiabatically eliminated, making this connection less obvious but not less real.

In the specific case of semiconductor microcavities referred to by Sich *et al.*[1], the relevance of the material component has been envisaged since the very first studies of cavity solitons in semiconductor systems[2,5], and the impact of material timescales on cavity solitons nucleation and motion has actually been discussed by Pedaci *et al.*[3] and Ackemann *et al.*[4], among others. For instance, dedicated numerical analyses[6] have shown that forcing a spatial separation of the material and optical components of a cavity soliton causes it to disappear, further demonstrating the intrinsic 'light–matter' nature of cavity solitons in semiconductor microcavity models. Perhaps even more significantly, this composite nature has been exploited in experiments that involve controlling cavity solitons by optically manipulating their material component[7].

In view of these observations, we believe that the terms 'light only' and 'pure-light' do not accurately reflect the nature of semiconductor cavity solitons and are therefore not helpful in framing a quantitative or qualitative comparison with polariton solitons. ☐

References

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Sich *et al.* reply: Regarding the terminology used in our recent publication (Sich, M. *et al. Nature Photon.* **6,** 50–55; 2012), we want to point out that it is known that both the linear and nonlinear parts of the refractive index contribute to soliton formation and are intrinsic optical properties of matter. Understanding the impact of these properties on the propagation of photons, such as dispersion, nonlinear frequency conversion and soliton formation, does not in most cases require a departure from the concept of photons. This is the limit of the 'weak coupling' between light and matter.

The first example of solitons we gave in the introduction of our work is that of solitons in optical fibres, which are pulses of light and are thus readily described in the limit of weak light–matter interaction. We therefore referred to these as 'light-only solitons'. In the case of strong coupling between light and matter, as is realized in the semiconductor microcavity used in our work, we deal with excitation frequencies where the cavity (and therefore light) resonance is absent and the excitonic resonance is also absent, so that neither light nor excitonic (matter) waves exist for the frequencies under consideration. Only half-light, half-matter polaritonic resonance exists at these frequencies, and we therefore refer to these as half-light, half-matter solitons — or 'polariton solitons'.

Investigations of microcavity solitons cited in the correspondence by Barland *et al.* deal with the case of weak coupling, where the energy levels of photons and material excitations do not hybridize and no polaritonic quasiparticles are formed. As such, in our terminology, this falls into the category of light-only solitons, which, as in optical fibres and other settings, cannot exist without the surrounding matter. In this respect we should also mention that adiabatic or non-adiabatic dynamics of the material excitations is a factor that is secondary to the existence (or non-existence) of polaritonic energy levels and to the choice of operating frequency with respect to these levels. We hope our comments here address the terminology concerns discussed in the correspondence by Barland *et al.* ☐

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