Ultrafast All-Optical Cross-Switching Schemes as Logical Operations Based on Dual-Wavelength Interaction in Soft Glass Multicore Fiber

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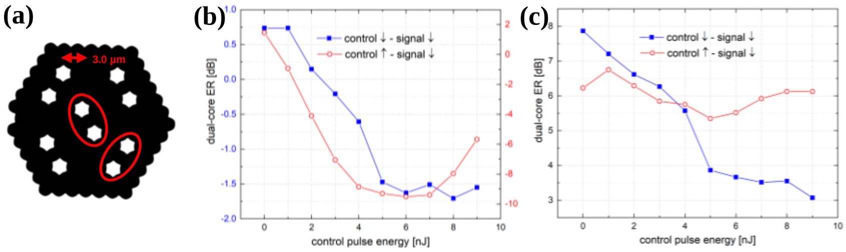
Coupled nonlinear waveguides represent a promising approach for all-optical signal processing tasks with useful applications in telecom, quantum information, and spectroscopy. This contribution focuses on a study of a multicore, highly nonlinear soft glass fiber with advantageous properties allowing self-switching [1] or cross-switching [2] of sub-100 fs pulses at low switching energies. Following our preliminary achievements, we performed an in-depth analysis of the dual-wavelength nonlinear switching potential of the fiber containing five separated dual-core units (DCUs) with different degrees of asymmetry (Fig. 1a). A complex study was performed, sequentially addressing all 5 DCUs under fiber length optimization and various control-signal beam input combinations. The experimental setup has been detailed in [2]. It consists of two synchronized fs sources operating at a 1 kHz repetition rate: 1) a 1030 nm, 250 fs control source from a commercial ultrafast Yb:CaF_2 amplifier, and 2) a 1550 nm, 80 fs signal source from an optical parametric amplifier, pumped by the second harmonic of the basic amplifier. The two pulse sequences were combined into a single beam with a dichroic mirror, temporally synchronized, and the energy of the signal pulses was set to 100 pJ to ensure their linear propagation. The nonlinear switching was controlled by varying the control pulse energy in the range of 1-10 nJ, and the combined beams were coupled into the fiber using a 50x microobjective. The fiber's output facet was imaged onto the chip of an IR camera by another 40x microobjective. Independent alignment of the signal beam was ensured by a tunable telescope and a mirror situated before the dichroic mirror. Selective launching of the control and signal beams into one of the two fiber cores was realized in a way that allowed four combinations for each DCU. Series of signal field output spatial distributions were registered by the camera as a function of control pulse energy for each combination. After processing the results, graphs of dual-core signal extinction ratio (ER = 10log(E_1/E_2) in dB, where $E_{1,2}$ is the output energy in the corresponding core) vs. input control pulse energy were created, depending on DCU selection, control/signal input combination, and fiber length.



(d)

combi-nation	1. INPUT different cores ?	2. INPUT C↓ ?	observation (energy de-pendence)	OUTPUT switch ?
C↓ + S↓	0	1		1
C↓ + S↑	1	1		1
C↑ + S↓	1	0		1
C↑ + S↑	0	0		0

Fig. 1 (a) Cross-section of the multicore fiber - the presented units are marked. Dual-core output signal extinction ratio vs. control energy for two input combinations in the case of (b) side DCU with symmetric character and (c) central DCU with asymmetric character. (d) Logical OR operation table realized in the case of the side unit.

The graphs in Fig. 1b,c present investigations of the central and one selected side DCU of the same fiber with an optimized length of 12 mm. In the case of the side unit, similar sign-changing ER dependencies were registered, indicating symmetric DCU due to the invariance of the choice of the control core excitation. In contrast, the central unit ER curves show significant input energy dependence only when the control beam was launched into the lower core of the unit. The same registration was performed for the remaining two combinations (C↓ – S↑, C↑ – S↑) investigating both DCUs. In summary, only the C↑ – S↑ combination resulted in no switching performance for the side unit, which means the realization of a logical OR operation setting: 1. logical input is 1 when the control and signal are launched into different cores, 2. logical input is 1 in the case of C↓, and logical output is 1 when ER sign exchanges by increasing input energy, i.e., switching takes place (Fig. 1d). Investigating the central unit, a logical AND operation was realized because only the combination C↑ – S↑ resulted in switching. These novel outcomes pave the way for the application of such multicore fibers in digital operations in the C-band, enabling more operations within the same short fiber piece by selecting the appropriate dual-core unit.

References

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