Ultrafast lasers have a crucial function in many fields of science; however, up to now, high-energy pulses directly from compact, efficient and low-power semiconductor lasers are not available. Therefore, we introduce a new approach based on temporal compression of the continuous-wave, wavelength-swept output of Fourier domain mode-locked lasers, where a narrowband optical filter is tuned synchronously to the round-trip time of light in a kilometre-long laser cavity. So far, these rapidly swept lasers enabled orders-of-magnitude speed increase in optical coherence tomography. Here we report on the generation of ~60–70 ps pulses at 390 kHz repetition rate. As energy is stored optically in the long-fibre delay line and not as population inversion in the laser-gain medium, high-energy pulses can now be generated directly from a low-power, compact semiconductor-based oscillator. Our theory predicts subpicosecond pulses with this new technique in the future.