Eur. Phys. J. Special Topics **224**, 2527–2528 (2015)

DOI: 10.1140/epjst/e2015-02561-1

THE EUROPEAN PHYSICAL JOURNAL SPECIAL TOPICS

Editorial

# Science and applications of the coherent amplifying network (CAN) laser

Gérard Mourou

IZEST, Ecole Polytechnique, 91128 Palaiseau, France

Received 10 July 2015 / Received in final form 31 August 2015
Published online 26 October 2015

Accelerators are today in every walk of science and life [1]. High intensity lasers drive frontiers of contemporary science. Lasers in the TW and PW regime have the potential to replace conventional accelerators with the distinct advantage to be dramatically shorter by a factor of a thousand or more [2]. For instance, electrons are accelerated to few GeV over only few centimeters, representing three to fours orders of magnitude higher accelerating gradients than traditional RF-based accelerators can offer. The approach was proposed in 1979 [3], where a strong laser pulse [4], moving in a plasma creates a wake in which electrons are trapped and violently accelerated. In addition, under ultra high intensity, high energy protons over 100 MeV have been demonstrated as well as high energy radiation greater that MeV [5]. Key to laser-driven accelerators, ion, X-Ray, or Gamma-Ray production are ultra high peak power lasers at the petawatt level [6]. However, current petawatt laser exhibits low repetition rates (state-of-the-art is about 1 Hz) due to thermo-optical character in their gain medium, resulting in low average powers in the 50 W range. In addition, a rather poor wall-plug efficiency (electrical power to optical power) of $10^{-3}\%$ avoids any scaling perspectives. Hence, state-of-the-art high peak power laser system cannot pretend to be tomorrow's replacement to conventional RF Technology –a new class of ultrafast lasers is urgently needed. Under the ICFA-ICUIL [2] initiative, laser experts in the field of particle acceleration and high intensity lasers defined target parameters of a future laser system should deliver to pave the way for a new kind of accelerator technology revolutionizing fundamental science and applications. The following laser parameters are envisaged for what could be a future linear e–e+ collider: peak power in the PW regime, defined by a 10's of Joules of pulse energy and an ultrashort pulse duration below 50 fs, in combination with an unparalleled average power exceeding 100 kW even exceeding the megawatt level, implying repetition rates of >10 kHz. These extreme parameters should be contained in a beam of excellent spatial quality, featuring outstanding temporal stability and temporal contrast. An excellent wall-plug efficiency of >30% is an essential condition that such average powers are realized in a cost effective, economic and compact way. Overall, any known laser technology known today faces severe issues, with current performance orders of magnitude below these target parameters. Inspired by these ground-breaking challenges under the Eu leadership, the International Coherent Amplification Network (ICAN) group was formed. It combines the complementary expertise of science authorities in the field of high performance fiber amplifiers, theoretical and applied optics of optical systems and finally ultra high intensity lasers. ICAN aspired to study the fundamentals of interferometric amplification i.e. spatially separated amplification followed by coherent addition, of ultrashort laser pulses as the underlying concept of a breakthrough in laser physics. In detail ICAN has studied:

1) average/peak power and efficiency limits of coherently combined ultrafast laser systems
2) synchronization, spatial and temporal recombination of a large number of fibers amplifiers
3) temporal and spatial beam quality, combining efficiency of coherent addition, amplitude and phase stability as a function of the number of fibers and their individual performance
4) reduction of pulse duration and manipulation of pulse shape.

In conclusion, this EPJ ST issue summarizes the conclusions resulting from the ICAN study, over existing high peak power lasers and could therefore lead to the successful replacement of RF-accelerators by laser driven accelerators. It efficaciously addresses scientific, industrial, and societal grand challenges: future colliders, vacuum physics, Higgs factories, high flux proton & neutron sources, applications such as nuclear transmutation, energy-specific gamma beams for isotope identification with high fluence as well as in medicine with nuclear pharmacology and proton therapy [2]. The applications have been recently extended to include orbital debris remediation [9,10] which aims to clean up the millions of debris fragments that have been produced as the results of the numerous launches since the beginning of the space era in 1960's.

## References

1. C.V. Shank, W. Henning, *Accelerators for America's Future*, Symposium report, June 2010, Department of Energy, `http://www.acceleratorsamerica.org/report/index.html`
2. W. Leemans, et al., ICFA Beam Dyn. Newslett. **56**, 10 (2011)
3. T. Tajima, J. Dawson, Phys. Rev. Lett. **43**, 267 (1979)
4. D. Strickland, G. Mourou, Opt. Commun. **56**, 219 (1985)
5. G. Mourou, T. Tajima, S. Bulanov, Rev. Modern Phys. **78**, 309 (2006)
6. M.D. Perry, G. Mourou, Science **264**, 917 (1994)
7. G. Mourou, D. Hulin, A. Galvanauskas, The road to High Peak Power and High Average Power Laser: Coherent Amplification Network (CAN), AIP Conference Proceedings, Third International Conference on Superstrong Fields in Plasmas, Vol. 827, edited by D. Batani, M. Lontano (2006), p. 152
8. G. Mourou, B. Brocklesby, T. Tajima, J. Limpert, Nat. Photon. **7**, 258 (2013)
9. R. Soulard, et al., Acta Astron. **105**(1), 192 (2014)
10. T. Ebisuzaki, et al., Acta Astron. **112**, 102 (2015)