§10. Complexity Paradigm of Stimulated Raman Backscattering in a Nonlinear Laser-plasma

Škorić, M.M., Nikolić, Lj. (NRC, Ottawa, Canada),
Ishiguro, S.

Strong laser plasma interactions are a useful test bed for exploring a rich variety of nonlinear and complex plasma phenomena. As a rule, they include a number of important 3-wave resonant instability models, involving laser pump parametric coupling to plasma eigen-modes. In laser fusion, great concern is about a stimulated Raman back- scattering (BRS) on electron plasma waves in underdense plasmas that results in a laser energy loss and target preheating [1-2]. Complexities related to a long laser pulse and long plasma-scale modeling and simulations of large anomalous BRS by pF3D code for NIF fusion targets at Livermore, have been recognized [1]. More recently, large effort is underway to reach ultra-high laser intensities at multi-exawatts and beyond, relevant to relativistic, nuclear and high-energy physics. At extreme laser power standard CPA laser technique fails and has to be overcome by novel approaches, such as using plasmas. In particular, Raman-BRS amplification [3,4], proposed a counter-propagating pico-second laser pump with a femto-second seed which resonate with the plasma wave to amplify by BRS. Still, simulations and few experiments have uncovered high BRS sensitivity and a narrow parameter window to avoid parasitic instabilities (FRS, RMI, etc.) and nonlinear pulse destruction as laser pump propagates along tenuous plasmas [4,5]. Here, we revisit the standard 3-coupled mode model of stimulated Raman backscatter (BRS) to show that the condition for an absolute instability [2,5] can be readily satisfied in uniform plasmas, driving a large BRS from a background noise. E.g., for moderate pump, ~ 10^{14} W/cm^2, over ~ *10* microns in underdense plasma, an absolute BRS could dominate. It sets in for interaction length-L_0 shorter than, both, the plasma-L and absorption length-L_a; $L_0 = (V_e V_s)^{1/2}/\gamma_0$; γ_0 -growth rate, V_e and V_s, plasmon and BRS group velocity, respectively. We further point out generic features of the BRS evolution, which due to a nonlinear frequency shift, instead to a steady-state, saturates via quasi-periodic intermittent route to chaos (Fig. 1), bringing incoherence, even before the plasma wave breaking [2,5]. Furthermore, an intermediate intensity regime with large coherent quasi-periodic pulsations can be exploited in an original proposal for ultra-short (FS) pulse generation by BRS in a thin underdense exploding foil plasma [5], with the parameter scaling investigated by theory and relativistic particle simulations, with some ideas for proof-of-principle experiments, given (Fig. 2).

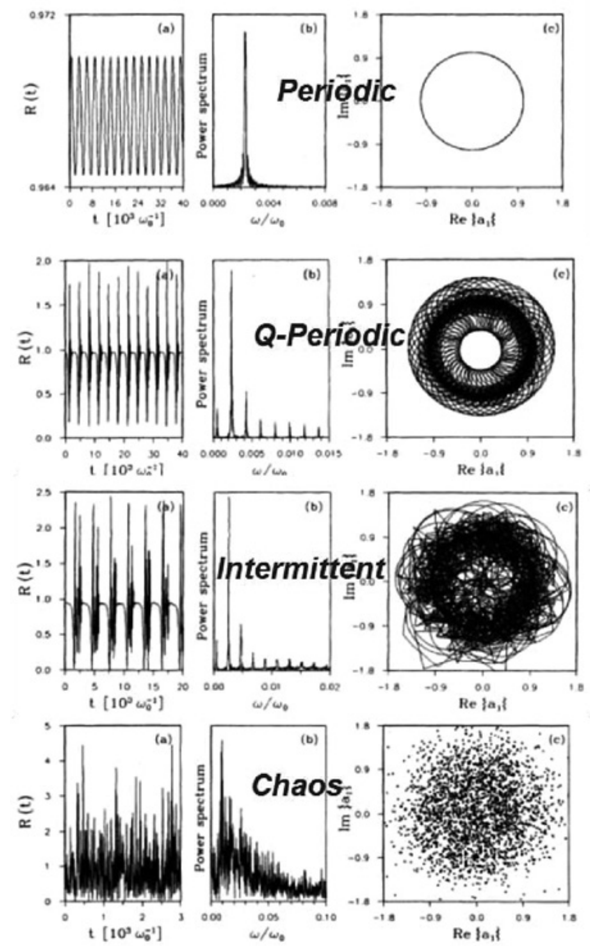

Fig .1 Route to Complexity, in BRS Reflectivity, Spectrum and Phase diagrams, with the increasing laser intensity.

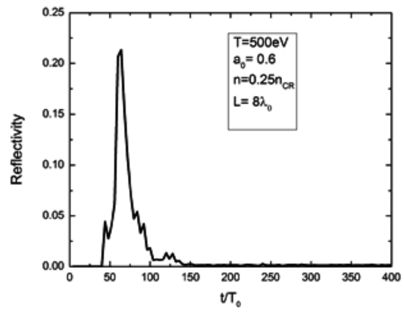

Fig.2. Raman compression into FS pulse in exploding foil plasma with PS laser pump, by a relativistic PIC simulation.

1. D. Hinkell, et al., Phys. Plasmas **18**, 056312 (2011).
2. M. Kono and M.M. Škorić, in *Nonlinear Physics of Plasmas*, Springer (2010).
3. G.A. Mourou, et al., Optics Comm. **285**, 720 (2012).
4. R.M.G.M. Trines, et al. Nature Physics **7**, 87 (2011).
5. M.M. Škorić, et al. , in AIP Conf. Proc. **406**, 381 (1997); ibid, **1188**, 15 (2009).