Part 1: Proposed Educational Contribution within the School of Mathematics and Physics (QUB)

Part 2: Anticipated Research on Laser-produced Plasmas in the Centre for Plasma Physics

Research Focus: Nonlinear Excitations in Plasma Physics

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Part 1a: Anticipated Course Work

- Teaching, postgraduate and/or
advanced undergraduate level courses (proposed):

 * Nonlinear Methods in Plasma Physics

 Nonlinear ES/EM modes, solitons, wave-wave coupling in laser plasmas, modulational instabilities, relativistic effects
 in high-power laser pulses …

 * The Physics of Complex (Dusty) Plasmas (CPs)

 CP waves, dust charging, charging instabilities, CP kinetic theory, dusty plasma "crystals" …

 * Nonlinear Science (advanced topics)

 Generic nonlinear PDEs, soliton theory, reductive perturbation techniques, wave modulation, chaos …

Part 1a : Anticipated Course Work *(continued)*

- Teaching: undergraduate courses, elementary or advanced level (proposed):

  * Fundamentals of Plasma Physics
  * Mathematical Methods for Physicists

    Elementary or advanced level
  * Statistical Mechanics, Kinetic Theory
  * Introduction to Nonlinear Physics
  * …

Part 1b: Contribution to Curriculum Development & Course Unit Design and Revision

- Existing programmes: participation, enrichment;

- New programmes, anticipated, to establish:

• Master's Degree Programme on Plasma Physics
offered by CPP *(possibility, proposed)*

• Master's Level Programme on Nonlinear Physics
in coordination with other Research Units
(possibility, proposed)

- Revision & constant update of course material;
+ student projects & handouts

Part 1c: Supervision of Student Work

- Postgraduate level: PhD research work
  - providing topics, inspiration, constructive feedback and follow-up, in collaboration with colleagues of CPP
  - relevance with current CPP research activities, inspiration by active focus topics
- Undergraduate level:
  - supervision of student work, projects, BSc dissertations
  - constant personal follow-up
  - human potential support via face-to-face philosophy
- Educational exchange:
  - active encouragement of student mobility & experience acquisition via EU mobility schemes + international contacts

Part 2: Research Work

- **2a. Activities - ambition:**

  * Theoretical Research in Plasma Physics

  * Publication of results in leading refereed journals and selected conference announcements & proceedings

  * Active seeking of research funding from national (RCUK) and EU sources, e.g. CEC DG RDT, ERC, ...

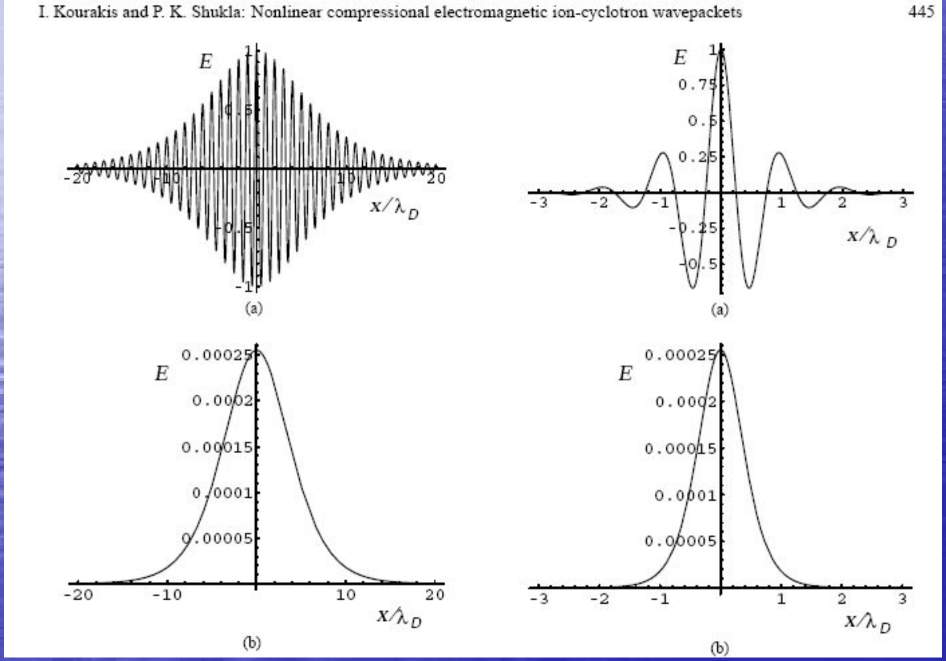
  * Guidance & vivid collaboration with staff members and students

  * Pursue & extend existing collaborations *(cf. below)* + develop further research links

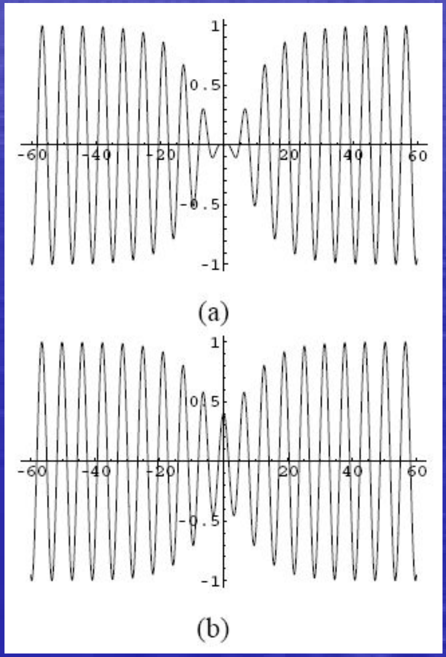
Part 2b. Research topics & active collaborations: an overview

(i) Nonlinear ES/EM excitations in laser-produced plasmas:

Localized pulse (soliton) formation, modulational instability, energy localisation, relativistic effects in high-P lasers, ...



From: Kourakis *et al,* NPG **12**, 441 (2005)



ibid, NPG **12**, 407 (2005)

Ongoing collaboration with: P K Shukla and co. (Bochum, Germany), R Bingham (Rutherford Appleton Lab., UK), L Stenflo, M Marklund & M Dieckmann (Sweden).

(ii) Beam-beam interactions in laser plasmas

053104-3 Instability and dynamics of two nonlinearly… Phys. Plasmas **13**, 053104 (2006)

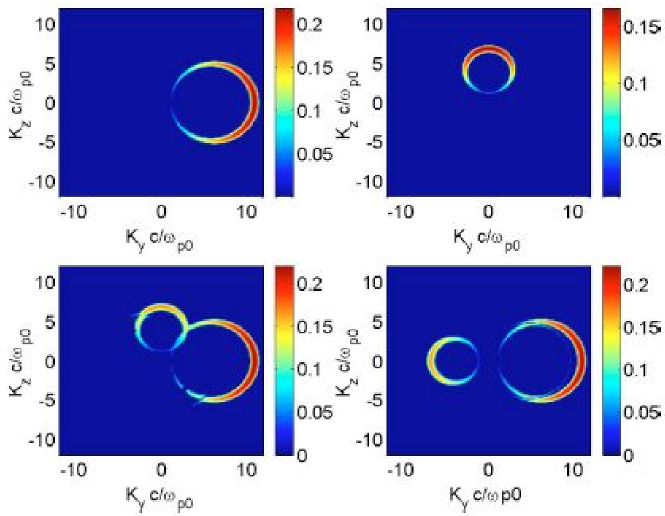


FIG. 1. (Color online). The normalized (by ω_{p0}) growth rates due to stimulated Raman scattering (case I) for single laser beams (upper panels) and for two laser beams (lower panel), as a function of the wavenumbers K_y and K_z. The upper left and right panels show the growth rate for beam A_1 and A_2, respectively, where the wave vector for A_1 is $(k_y,k_z)=(6,0)\omega_{p0}/c$ and the one for A_2 is $(k_y,k_z)=(0,4)\omega_{p0}/c$, i.e., the two beams are launched in the y and z directions, respectively. In the lower left panel, A_1 and A_2 are launched simultaneously at a perpendicular angle to each other, and in the lower right panel, the two beams are counterpropagating. We used the normalized amplitudes $|A_{10}|=|A_{20}|=0.1$ and the electron thermal speed $v_{Te}=0.01c$.

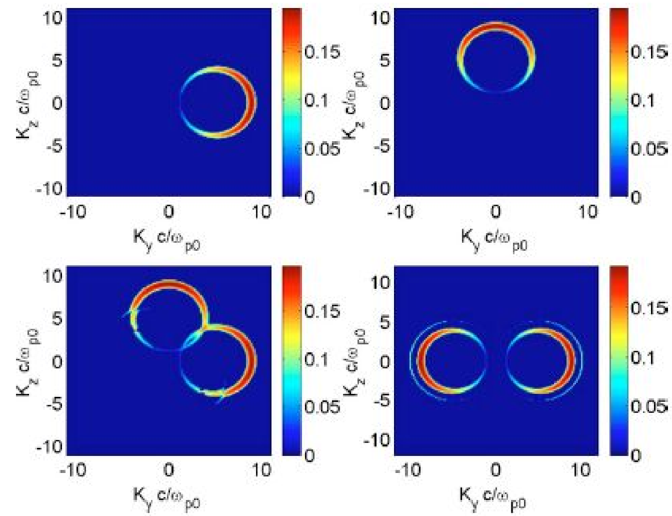
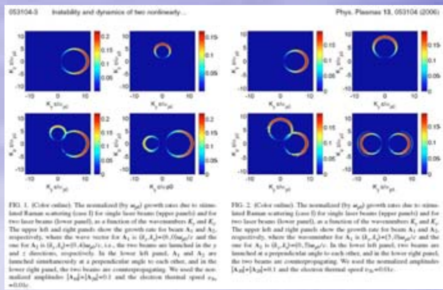


FIG. 2. (Color online). The normalized (by ω_{p0}) growth rates due to stimulated Raman scattering (case I) for single laser beams (upper panels) and for two laser beams (lower panel), as a function of the wavenumbers K_y and K_z. The upper left and right panels show the growth rate for beam A_1 and A_2, respectively, where the wavenumber for A_1 is $(k_y,k_z)=(5,0)\omega_{p0}/c$ and the one for A_2 is $(k_y,k_z)=(0,5)\omega_{p0}/c$. In the lower left panel, two beams are launched at a perpendicular angle to each other, and in the lower right panel, the two beams are counterpropagating. We used the normalized amplitudes $|A_{10}|=|A_{20}|=0.1$ and the electron thermal speed $v_{Te}=0.01c$.

From: Shukla *et al*, *PoP* **13**, 053104 (2006)

Ongoing collaboration with: P K Shukla and co. (Bochum, Germany)
& M Dieckmann (Linkjoping, Sweden).

(ii) Beam-beam interactions in laser plasmas 2 (RS)



Enhanced instability growth rate due to coupling, stimulated Raman scattering : localised NL electric field + interference pattern formation

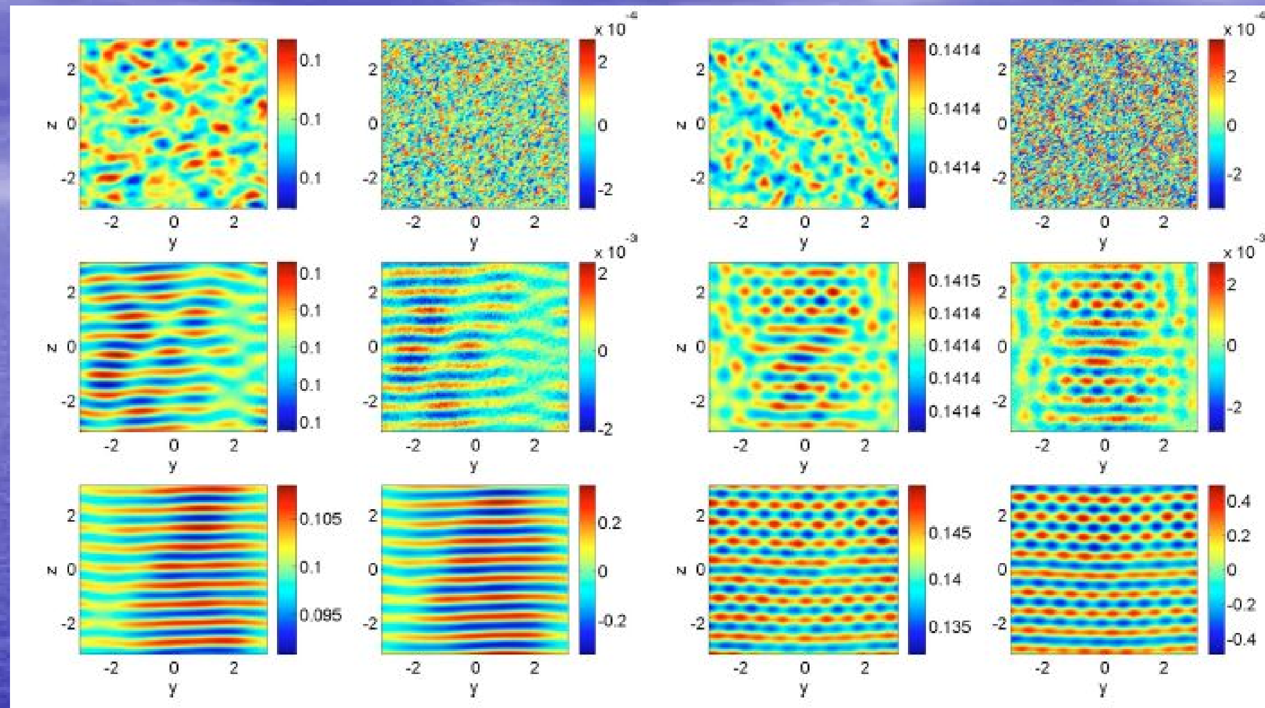


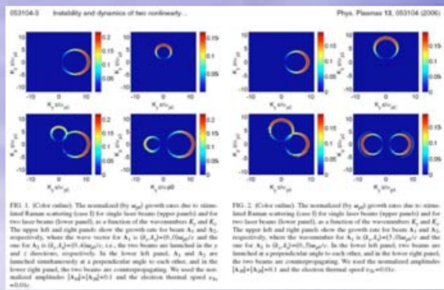
FIG. 5. (Color online). The amplitude of a single laser beam $|A_1|$ (left panels) and the electron density N_s (right panels) involving stimulated Raman scattering (case I), at times $t=1.0\omega_{p0}^{-1}$, $t=30\omega_{p0}^{-1}$, and $t=60\omega_{p0}^{-1}$ (upper to lower panels). The laser beam initially has the amplitude $A_1=0.1$ and wavenumber $(k_{1y},k_{1z})=(0,5)\omega_{p0}/c$. The electron density is initially perturbed with a small-amplitude noise (random numbers) of order 10^{-4}.

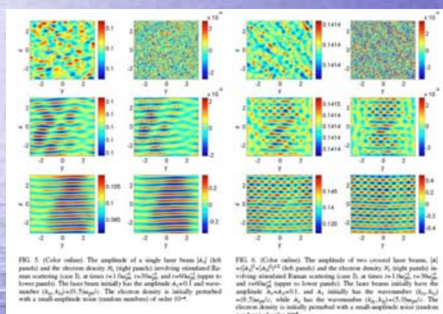
FIG. 6. (Color online). The amplitude of two crossed laser beams, $|A| = (|A_1|^2+|A_2|^2)^{1/2}$ (left panels) and the electron density N_s (right panels) involving stimulated Raman scattering (case I), at times $t=1.0\omega_{p0}^{-1}$, $t=30\omega_{p0}^{-1}$, and $t=60\omega_{p0}^{-1}$ (upper to lower panels). The laser beams initially have the amplitude $A_1=A_2=0.1$, and A_1 initially has the wavenumber $(k_{1y},k_{1z}) = (0,5)\omega_{p0}/c$, while A_2 has the wavenumber $(k_{2y},k_{2z})=(5,0)\omega_{p0}/c$. The electron density is initially perturbed with a small-amplitude noise (random numbers) of order 10^{-4}.

From: Shukla *et al, PoP* **13**, 053104 (2006)

Ongoing collaboration with: P K Shukla and co. (Bochum, Germany) & M Dieckmann (Linkjoping, Sweden).

(ii) Beam-beam interactions in laser plasmas 3 (BS)





Brillouin scattering: higher nonlinearity, localised envelope crest formation

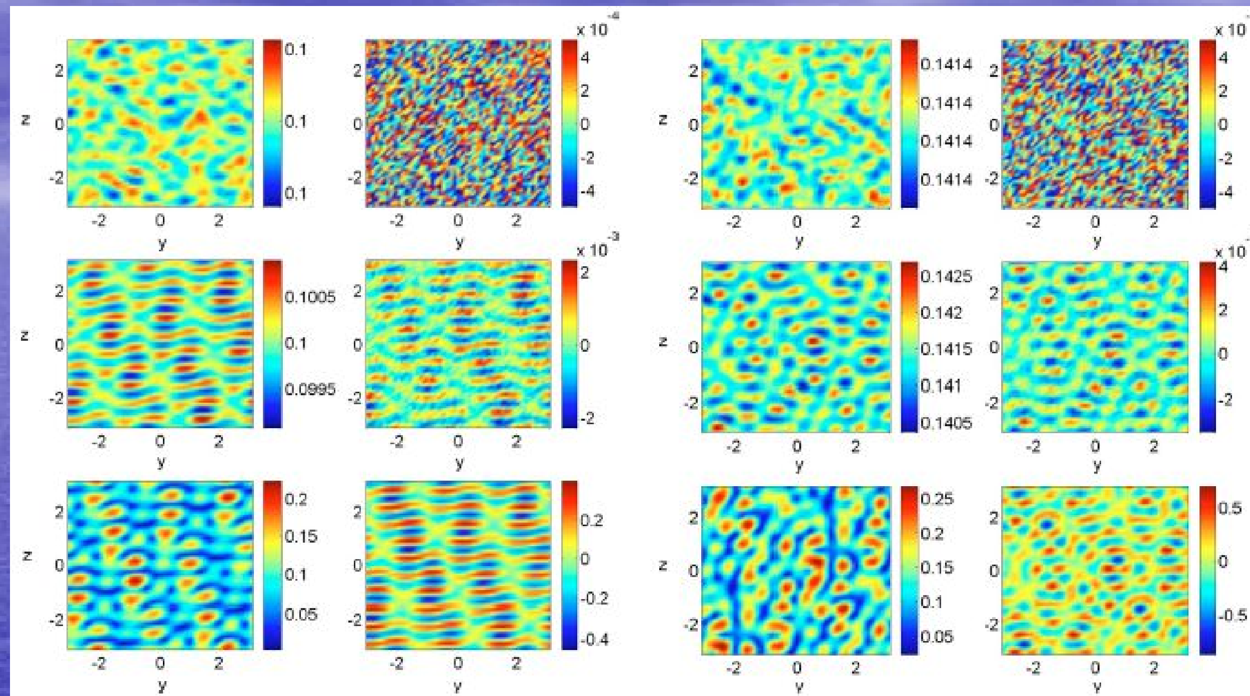


FIG. 7. (Color online). The amplitude of a single laser beam $|A_1|$ (left panels) and the electron density N_s (right panels) involving stimulated Brillouin scattering (case II), at times $t=1.5\omega_{p0}^{-1}$, $t=600\omega_{p0}^{-1}$, and $t=1200\omega_{p0}^{-1}$ (upper to lower panels). The laser beam initially has the amplitude $A_1=0.1$ and wavenumber $(k_{1y},k_{1z})=(0,5)\omega_{p0}/c$. The ion density is initially perturbed with a small-amplitude noise (random numbers) of order 10^{-4}.

FIG. 8. (Color online). The amplitude of two crossed laser beams, $|A|=(|A_1|^2+|A_2|^2)^{1/2}$ (left panels) and the electron density N_s (right panels) involving stimulated Brillouin scattering (case II), at times $t=1.0\omega_{p0}^{-1}$, $t=30\omega_{p0}^{-1}$, and $t=60\omega_{p0}^{-1}$ (upper to lower panels). The laser beams initially have the amplitude $A_1=A_2=0.1$, and A_1 initially has the wavenumber $(k_{1y},k_{1z})=(0,5)\omega_{p0}/c$, while A_2 has the wavenumber $(k_{2y},k_{2z})=(5,0)\omega_{p0}/c$. The electron density is initially perturbed with a small-amplitude noise (random numbers) of order 10^{-4}.

From: Shukla *et al, PoP* **13**, 053104 (2006)

Ongoing collaboration with: P K Shukla and co. (Bochum, Germany) & M Dieckmann (Linkjoping, Sweden).

(iii) Beam-plasma instabilities

Recent publications: Esfandyari *et al, PoP* **13**, 042305 (2006)
+ in preparation;

Ongoing collaboration: R Esfandyari and co. (Tabriz, Iran),
P K Shukla (Bochum, Germany).

(iv) Pair plasmas, e-p plasmas (e.g. in pulsars, or in laser assisted inertial fusion plasmas): NL ES/EM modes

Recent publications: Kourakis *et al, PoP* **14**, 022306 (2007)
Moslem *et al*, *PoP (accepted, to appear)*
Esfandyari *et al, PoP* **13**, 122310 (2006)
Esfandyari *et al, J.Phys.A* **39**, 13817 (2006)

Ongoing collaborations: F Verheest (Gent, Belgium),
N F Cramer (Sydney, Australia),
W F Moslem (Egypt, Von Humboldt Fellow),
R Esfandyari *and co.* (Tabriz, Iran),
D Melrose (Sydney, Aus.), anticipated visit.

(v) Complex (dusty) plasmas (weakly coupled): fundamental properties, NL waves, instabilities

Recent publications: Momeni *et al*, J. Phys. A *(submitted)*
El Taibany *et al*, PoP **13**, 062302 (2006)
Kourakis *et al*, NPG **12**, 407 (2005)

Ongoing collaboration: P K Shukla (Bochum, Germany),
F Verheest (Gent, Belgium),
S Vladimirov (Sydney, Aus), visit.

(vi) Dusty plasma crystals (*strongly* coupled): lattice waves, solitons, instabilities, discrete breathers

Recent publications: V Koukouloyannis *et al*, PRE *(submitted)*
B Farokhi *et al*, PoP **13**, 122304 (2006)
I Kourakis *et al*, PLA 351, 101 (2006)

Ongoing collaboration: P K Shukla (Bochum, Germany),
B Farokhi (Arak, Iran),
V Koukouloyannis (Thes/niki, Greece).

Addendum: Beyond Plasma Physics: topics from nonlinear science & NL optics:

(vii) Nonlinear metamaterials & left-handed media: EM wave propagation, pulse generation, NL effects

Recent publications: Kourakis *et al,* PRE *(submitted)*

PRE 72, 016626 (2005), Phys.Scr. 74, 422 (2006)

Coll.: G Tsironis, N Lazarides (Crete, Greece), PKS (Bochum)

(viii) Bose-Einstein Condensates (BECs)

Eur. Phys. J. B **46**, 381–384 (2005)
DOI: 10.1140/epjb/e2005-00271-7

THE EUROPEAN PHYSICAL JOURNAL B

Modulational instability criteria for two-component Bose–Einstein condensates

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[2] Department of Physics, Umeå University, 90187 Umeå, Sweden

(ix) Rogue (freak) waves (ocean surface crests)

PRL **97,** 094501 (2006) PHYSICAL REVIEW LETTERS week ending 1 SEPTEMBER 2006

Instability and Evolution of Nonlinearly Interacting Water Waves

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[2]*Institut für Theoretische Physik IV and Centre for Plasma Science and Astrophysics, Fakultät für Physik und Astronomie, Ruhr-Universität Bochum, D-44780 Bochum, Germany*
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Research collaborations and thematic investigations to be sustained in an active manner,

to the benefit of CPP/QUB and collaborating students/staff.

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Thank You!