Session 4

Posters:

FREE-SPACE PROPAGATOR AND MATRIX DIAGONALIZATION METHOD FOR RADIALLY AND AZIMUTHALLY POLARIZED BEAMS

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Abstract

We develop round-trip matrix diagonalization method for quantitative description of selection of radially- or azimuthally- polarized beams by birefringence-induced bi-focusing [1, 2] in a simple laser resonator. We employ different focusing between radially and tangentially polarized light in thermally stressed laser rods to obtain low-loss stable oscillation in radially-polarized LG (0,1)* mode. While the radially-polarized light can be well-focused through the aperture, the azimuthally-polarized light will suffer very high diffraction losses. This allows to select pure radially-polarized LG (0,1)* beam. We derive free-space propagator for the radially- and azimuthally- polarized LG(0,1)* modes and explain basic principles of mode selection by use of the round-trip matrix diagonalization method. Within this method, we calculate round- trip diffraction losses and the intensity distributions for the lowest- loss transverse modes. We show that for the considered laser configuration, the round-trip loss obtained for the radially-polarized LG (0,1)* mode, is significantly smaller than that of the azimuthally-polarized mode. Our experimental results, obtained with diode side-pumped Nd:YAG rod in flat- convex resonator, confirm the theoretical predictions. Pure radially-polarized LG (0,1)* beam with M^2=2.5 and output power of tens watt was achieved.

References

1. I. Moshe, S. Jackel, A. Meir, *Optics Letters*, **28** (2003) 807.
2. M.S. Roth, E.W. Wyss, H. Glur, H.P. Weber, *Optics Letters* **30**, (2005),1665

BACKWARD WAVE EXCITATION AND GENERATION OF OSCILLATIONS IN FREE-ELECTRON LASERS IN THE ABSENCE OF FEEDBACK -BEYOND THE HIGH GAIN APPROXIMATION

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Conventional (quantum) lasers, microwave tubes and free-electron lasers (FELs) are based on distributed interactions between electromagnetic radiation and gain media. When such devices are operating in an amplifier configuration, a forward wave is amplified while propagating in a polarized medium, in a stimulated emission process. Formulating a coupled mode theory for excitation of both forward and backward waves in a distributed gain medium, we have identified in previous works [1] conditions leading to efficient excitation of backward wave without any mechanism of feedback or resonator assembly.

The excitation of incident and reflected waves is described by a set of two coupled differential equations expressed in the frequency domain. The induced polarization is given in terms of an electronic susceptibility tensor, resulting in a coupling coefficient betweens the waves. In high-gain free-electron lasers, where the susceptibility is space dependent, the set includes two differential equations of the third order each.

In this work we extend our previous results in two directions:

1. We discuss the case of a complex coupling coefficient between the backward and forward waves and extend our previous results with respect to a real coupling coefficient, thus the present work discusses a more general and realistic case.

2. We discuss the solution of the same problem relaxing the “high gain” assumption. This leads to a more complex set of third order differential equations.

Analytical solutions of reflectance and transmittance for FELs are presented. It is found that when the solutions become infinite, the device operates as an oscillator, producing radiation at the output with no field at its input, entirely without any localized or distributed feedback.

[1] Yosef Pinhasi, Asher Yahalom, Yuri Lurie & Gad A. Pinhasi "Backward Wave Excitation and Generation of Oscillations in Distributed Gain Media and Free-Electron Lasers in the Absence Of Feedback" Proceedings of the 26th International Free-Electron Laser Conference, 14-17, 29 August -3 September 2004, Trieste, Italy.

SELF-FOCUSING DISTANCE OF HIGH POWER LASER PULSES PROPAGATING IN THE ATMOSPHERE

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An experimental research exploring the collapse distance of high power laser pulses propagating in air is presented. When laser power exceeds a critical value, the induced change of the refractive index due to the Kerr effect can overcome the diffraction, causing self-focusing of the beam. Beam intensity is increased to the point that multiphoton ionization of air molecules sets in. The generated electron density defocuses the beam. The dynamic balance between focusing due to the Kerr effect and defocusing due the plasma leads to the generation of a filament that can be guided over an extended distance. We explore the propagation distance at which this collapse of the laser pulse into filament occurs.

The collapse distance depends on the pulse power and its spatial profile. Self-focusing distance of a perfect Gaussian beam, collapsing into one single filament is proportional to the Rayleigh length of the beam divided by the square root of the power P. At higher powers small inhomogeneities at the bean initial spatial profile can break the laser beam into multiple filaments. This multiple filamentation occurs at length scale much shorter than the self-focusing distance. The growth length of those inhomogeneities is inversely proportional to the light intensity, therefore at high power the onset of filamentation distance scales as 1/P.

In this work we show experimental measurements of filamentation distance, both in the moderate power regime – when it scales as $1/P^{1/2}$, and at the high power regime – when it scales as 1/P. The experimental results are in a good qualitative and quantitative agreement with theoretical prediction. At very high powers – few hundreds time the critical power – the experimental results indicate a $1/P^{1/2}$ dependence, similar to the lower powers.

Control over the onset of filamentation distance at a fixed power is demonstrated via control over the beam initial divergence. The filaments duration distance in this case increase with the increasing of the onset distance.

Passive coherent addition of several eye-safe fiber lasers

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Abstract

Eyesafe fiber lasers typically have relatively low output energy. In order to obtain high output energy, we consider coherent addition of several low energy fiber lasers. The coherent addition is achieved with passive intra-cavity interferometric combiners, that allow for a robust and stable overall system. The design of the individual lasers, the coherent addition configuration, and the experimental results showing that high combining efficiency can be obtained will be presented.

PHASE ELEMENT CAN IMPROVE STABILITY OF LONGITUDINAL AND TRANSVERSE LASER MODES

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Abstract

We investigate influence of phase elements on the laser mode stability, in the inherently unstable regime where the separation between the frequencies of adjacent longitudinal modes is of the order of the laser gain bandwidth. In such lasers, e.g. CO_2 lasers, the effective gain of each transverse mode strongly depends on the exact position of its longitudinal mode frequencies with respect to the maximal gain frequency. Hence, the transverse modal content becomes extremely sensitive to sub-wavelength changes of the laser resonator length, which changes spontaneously on a sub-wavelength scale due to mechanical and thermal vibrations. We demonstrate an approach for stabilizing the transverse mode structure, inserting an intra-cavity binary phase element (BPE) that discriminates and selects a specific transverse mode, into the laser resonator. We show that the discrimination can be so strong that the selection of the single transverse mode remains stable despite changes of the resonator length.

Our theoretical calculations show that without the phase element, it would be possible to obtain laser operation with different transverse modes by properly adjusting the resonator length *L* so as to control the longitudinal modes. In contrast to this, with BPE the laser will operate only in a single transverse high-order mode. Our experimental data confirm these results. We used a CW CO_2 laser with resonator's length *L*=165 cm, inner tube diameter of 13 mm and output power of 3 W [1]. The back mirror was placed on a mount that allowed for sub-micron displacements along the axial z direction. Without the phase element, a sub-wavelength change of the resonator length *L* leads to a substantial change of the transverse mode distribution, whereby each transverse mode was repeated, as expected, after ΔL =5.3 μm= $\lambda/2$. With BPE, the selected transverse mode does not change with the change of the resonator length *L*. This indicates that the mode will remain stable with respect to mechanical and thermal vibrations.

We obtained only slight periodic variation in the output power and M^2, due to periodic variations of the resonance conditions as the resonator length *L* is varied.

[1] G.Machavariani, N.Davidson, A.A.Ishaaya, A.A.Friesem, *Opt.Comm*. **239**, 147, (2004)