On electron channeling in crossed laser beams of arbitrary polarization

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Channeling-2014, Capri

October 9, 2014

Contents

Crystal Channeling

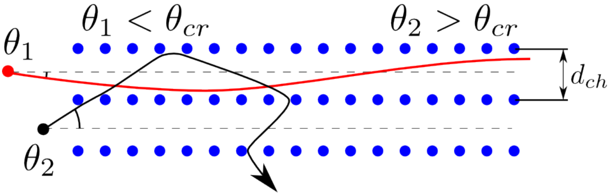


Figure : Channeled and non-channeled particles trajectories.

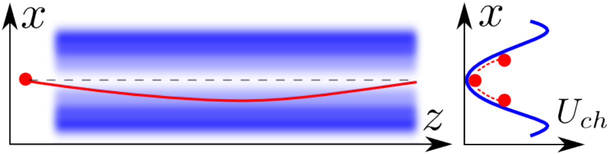


Figure : Channeling in averaged lattice potential and the schematic averaged potential.

So many different channelingS

- Channeling of neutral particles in capillaries (X-ray channeling)
- Channeling of ions in carbon nanotubes
- Electrons channeling in ion cavity
- Electrons channeling in crossed laser beams

Optical lattice instead of crystal lattice

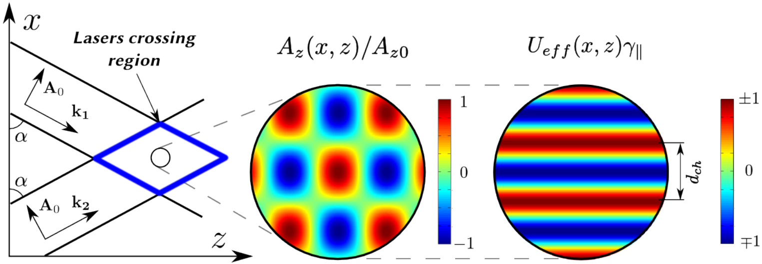
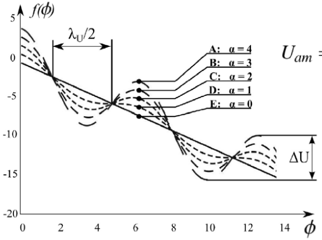


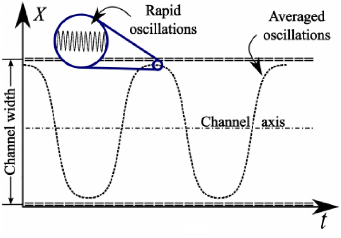
Figure : P-polarized laser beams of equal intensity crossed at angle α, field structure in the overlapping region and averaged potential in this region.

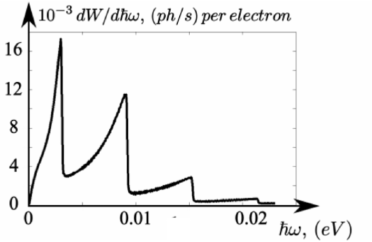
Our previous results (See [11, 13, 14] in Refs)



$$U_{am} = \frac{e^2 A_0^2 k^2 [(1+\cos^2\alpha)\beta_{\|}^2 - \cos(2\alpha) - 2\beta_{\|}\sin\alpha]}{2\gamma_{\|} m_e \omega^2 (1-\beta_{\|}\sin\alpha)^2}$$

$$\beta_{\|inv}(\alpha) = \frac{\sin\alpha \pm \cos\alpha\sqrt{[1+\cos(2\alpha)]}}{1+\cos^2\alpha}$$





Previous researches

The reflection of electrons from standing light waves

P. L. Kapitza and P. A. M. Dirac

Mathematical Proceedings of the Cambridge Philosophical Society / Volume 29 / Issue 02 / May 1933, pp 297 - 300
DOI: 10.1017/S0305004100011105, Published online: 24 October 2008

Link to this article: http://journals.cambridge.org/abstract_S0305004100011105

See [17] in Refs.

Previous researches

“Channeling” of Relativistic Electrons in a Periodic EM Potential

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Sezione Fisica - Dipartimento di Energetica, University of Rome, Rome, Italy

LI FULI*
Centro di Fisica Teorica - Trieste, Italy

From the book
Trends in Quantum Electronics: Proceedings of the 2nd Conference, Bucharest, September 2-6, 1985

See also [10, 15].

Previous researches

Free-electron laser based on the effect of channeling in an intense standing light wave

M. V. Fedorov, K. B. Oganesyan, and A. M. Prokhorov
General Physics Institute, Academy of Sciences of the USSR, 38 Vavilov Street, 117942 Moscow, USSR

(Received 9 December 1987; accepted for publication 31 May 1988)

Channeling of electrons moving across an intense standing light wave is described. This effect is proposed to be used for the creation of a free-electron laser. Its linear gain is found and estimated.

See [12] in Refs.

Previous researches

Channeling, collimation, and radiation of relativistic electrons in ultrastrong nonuniform optical fields

A. V. Andreev and S. A. Akhmanov
M. V. Lomonosov Moscow State University, 119899, Moscow

(Submitted 27 November 1990)
Pis'ma Zh. Eksp. Teor. Fiz. **53**, No. 1, 18–20 (10 January 1991)

Relativistic electron beams can be channeled and collimated in intense interference optical fields. Certain aspects of the radiation by a channeled electron are discussed.

See also [1, 2].

Previous researches

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **16**, 100703 (2013)

Betatron emission from relativistic electrons in a high intensity optical lattice

I. A. Andriyash,[1,2,*] E. d'Humières,[2] V. T. Tikhonchuk,[2] and Ph. Balcou[2]

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(Received 30 May 2013; published 30 October 2013)

We describe theoretically and numerically the interaction of a laser- or LINAC-accelerated beam of relativistic electrons with a high intensity optical lattice, resulting from the superposition of two transverse laser pulses. The bunch is trapped and guided within the potential channels of the optical lattice, leading to betatron oscillations. We describe the emission from individual particles and from the bunch, and analyze its spectrum, considering the dominant incoherent radiation as well as possible effects of partial coherency. Analysis of the emitted radiation should provide useful information on the characteristics of the electron beam, and its interaction with the optical lattice.

DOI: 10.1103/PhysRevSTAB.16.100703 PACS numbers: 41.60.Ap, 41.75.Jv, 42.65.Jx

See also [3, 4, 5, 6, 7, 8].

Previous researches

VOLUME 75, NUMBER 25 PHYSICAL REVIEW LETTERS 18 DECEMBER 1995

Relativistic Ponderomotive Force, Uphill Acceleration, and Transition to Chaos

D. Bauer, P. Mulser, and W.-H. Steeb*

Theoretical Quantum Electronics (TQE), Technische Hochschule Darmstadt, Hochschulstrasse 4A, D-64289 Darmstadt, Federal Republic of Germany

(Received 22 August 1995)

Starting from a covariant cycle-averaged Lagrangian the relativistic oscillation center equation of motion of a point charge is deduced, and analytical formulas for the ponderomotive force in a traveling wave of arbitrary strength are presented. It is further shown that the pondermotive forces for transverse and longitudinal waves are different; in the latter, uphill acceleration can occur. In a standing wave there exists a threshold intensity above which, owing to transition to chaos, the secular motion can no longer be described by a regular ponderomotive force.

See [9] in Refs.

Previous researches

PHYSICAL REVIEW A **72**, 043401 (2005)

Relativistic reversal of the ponderomotive force in a standing laser wave

A. L. Pokrovsky and A. E. Kaplan*
Electrical and Computer Engineering Department, The Johns Hopkins University, Baltimore, Maryland 21218, USA
(Received 1 August 2005; published 11 October 2005; publisher error corrected 12 October 2005)

Effect of relativistic reversal of the ponderomotive force (PF), reported earlier for a collinear configuration of electron and laser standing wave [A. E. Kaplan and A. L. Pokrovsky, Phys. Rev. Lett., **95**, 053601 (2005)], is studied here theoretically for various types of polarizations of the laser beam. We demonstrated that the collinear configuration, in which the laser wave is linearly polarized with electric field $\vec{E}$ parallel to the initial electron momentum $\vec{p}_0$, is the optimal configuration for the relativistic reversal. In that case, the transverse PF reverses its direction when the incident momentum is $p_0 = mc$. The reversal effect vanishes in the cases of circular and linear with $\vec{E} \perp \vec{p}_0$ polarizations. We have discovered, however, that the counter-rotating circularly polarized standing waves develop attraction and repulsion areas along the axis of laser, in the laser field whose intensity is homogeneous in that axis, i.e., has no field gradient.

DOI: 10.1103/PhysRevA.72.043401 PACS number(s): 42.50.Vk, 34.80.Qb, 61.14.−x, 42.65.Ky

See also [18, 19].

Previous researches

PHYSICAL REVIEW A **83**, 063810 (2011)

Polarization-dependent ponderomotive gradient force in a standing wave

P. W. Smorenburg, J. H. M. Kanters, A. Lassise, G. J. H. Brussaard, L. P. J. Kamp, and O. J. Luiten*
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P.O. Box 513, NL-5600 MB Eindhoven, The Netherlands
(Received 2 February 2011; published 13 June 2011)

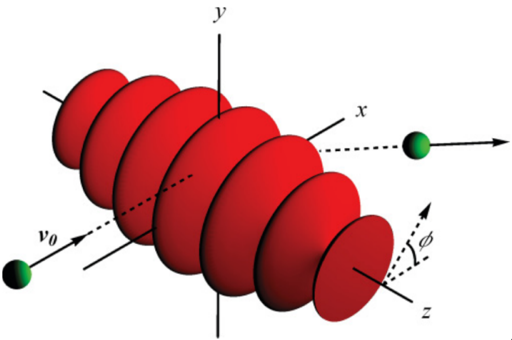
The ponderomotive force is derived for a relativistic charged particle entering an electromagnetic standing wave with a general three-dimensional field distribution and a nonrelativistic intensity, using a perturbation expansion method. It is shown that the well-known ponderomotive gradient force expression does not hold for this situation. The modified expression is still of simple gradient form but contains additional polarization-dependent terms. These terms arise because the relativistic translational velocity induces a quiver motion in the direction of the magnetic force, which is the direction of large field gradients. Consistent perturbation expansion of the equation of motion leads to an effective doubling of this magnetic contribution. The derived ponderomotive force generalizes the polarization-dependent electron motion in a standing wave obtained earlier [A. E. Kaplan and A. L. Pokrovsky, Phys. Rev. Lett. **95**, 053601 (2005)]. Comparison with simulations in the case of a realistic, nonidealized, three-dimensional field configuration confirms the general validity of the analytical results.

DOI: 10.1103/PhysRevA.83.063810 PACS number(s): 42.50.Wk, 41.75.Jv, 42.25.Ja, 02.30.Mv

See [20] in Refs.

Previous researches

Smorenburg *et al*
PRA 83 (2011)



See [20] in Refs.

Previous researches

PRL **113,** 014801 (2014) PHYSICAL REVIEW LETTERS week ending 4 JULY 2014

Anomalous Radiative Trapping in Laser Fields of Extreme Intensity

A. Gonoskov,[1,2,3,*] A. Bashinov,[2,3] I. Gonoskov,[4] C. Harvey,[5] A. Ilderton,[1] A. Kim,[2,3]
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[1]*Department of Applied Physics, Chalmers University of Technology, SE-41296 Gothenburg, Sweden*
[2]*Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod 603950, Russia*
[3]*University of Nizhny Novgorod, Nizhny Novgorod 603950, Russia*
[4]*Department of Physics, Umeå University, SE-90187 Umeå, Sweden*
[5]*Centre for Plasma Physics, Queen's University Belfast, Belfast BT7 1NN, United Kingdom*
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(Received 5 August 2013; published 2 July 2014)

We demonstrate that charged particles in a sufficiently intense standing wave are compressed toward, and oscillate synchronously at, the antinodes of the electric field. We call this unusual behavior anomalous radiative trapping (ART). We show using dipole pulses, which offer a path to increased laser intensity, that ART opens up new possibilities for the generation of radiation and particle beams, both of which are high energy, directed, and collimated. ART also provides a mechanism for particle control in high-intensity quantum-electrodynamics experiments.

See [16] in Refs.

Motivation

- Clarify the dynamics in crossed fields
- Beam diagnostics
- Beam manipulation
- Radiation source

General scheme of the considered system

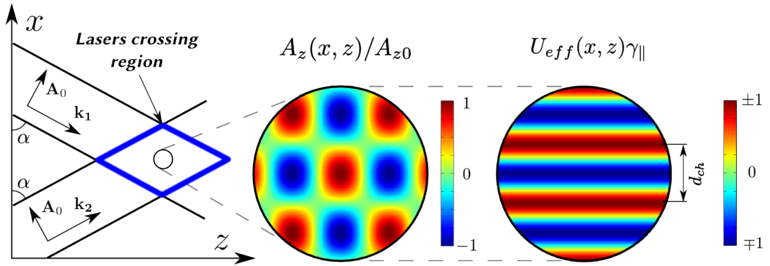
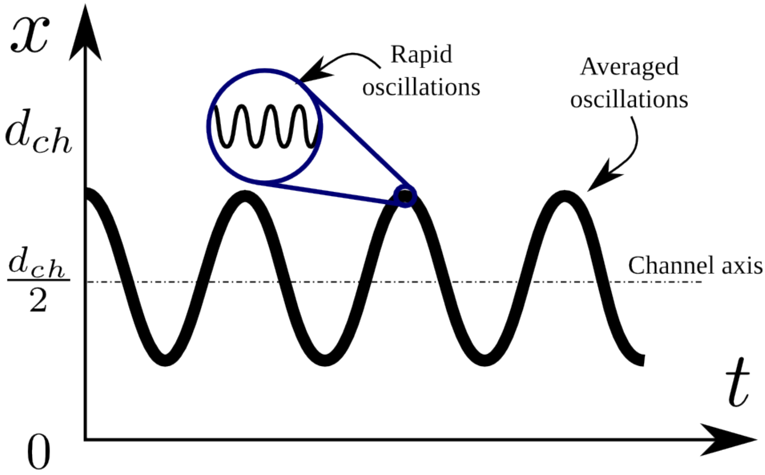


Figure : P-polarized laser beams of equal intensity crossed at angle α, field structure in the overlapping region and averaged potential in this region.

Electron trajectory



System effective potential

$$U_{eff} \sim U_{am} \cos\left(2kx\cos\alpha\right),$$

where U_{am} is potential amplitude.

$$U_{am} = \frac{e^2 A_0^2 k^2 [(1+\cos^2\alpha)\beta_{\parallel}^2 - \cos(2\alpha) - 2\beta_{\parallel}\sin\alpha]}{2\gamma_{\parallel} m_e \omega^2 (1-\beta_{\parallel}\sin\alpha)^2},$$

where e is the electron charge,
$\beta_{\parallel}$ is the electron velocity projection on Oz-axis normalized by c,
$\gamma_{\parallel} = 1/\sqrt{1-\beta_{\parallel}^2}$.

$$d_{ch} = \pi/(k\cos\alpha)$$

Potential characteristics

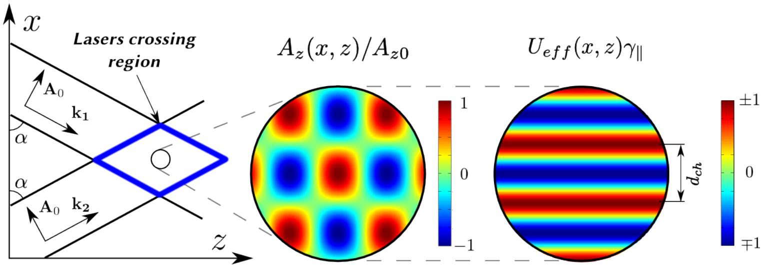


Figure : P-polarized laser beams of equal intensity crossed at angle α, field structure in the overlapping region and averaged potential in this region.

System effective potential

$$U_{am}(\alpha, \beta_{\|}) = \frac{e^2 A_0^2 k^2}{2\gamma_{\|} m_e \omega^2} \frac{[(1 + \cos^2\alpha)\beta_{\|}^2 - \cos(2\alpha) - 2\beta_{\|}\sin\alpha]}{(1 - \beta_{\|}\sin\alpha)^2}$$

Potential amplitude depends on $\beta_{\|}$ and α

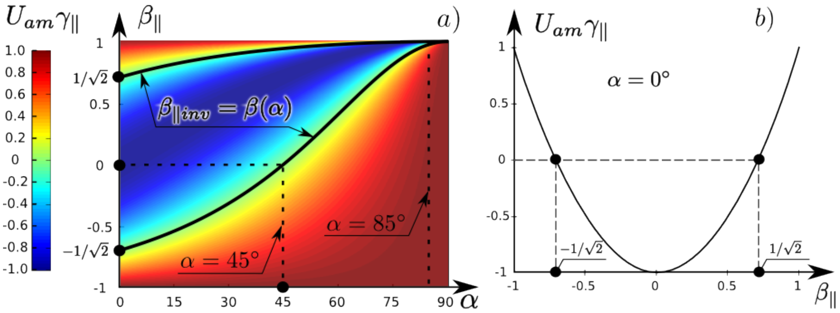
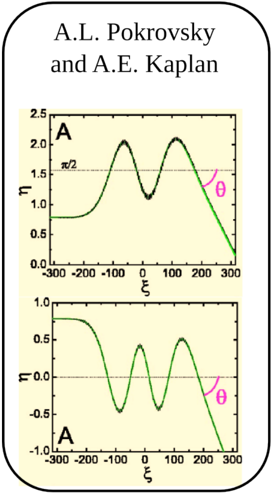
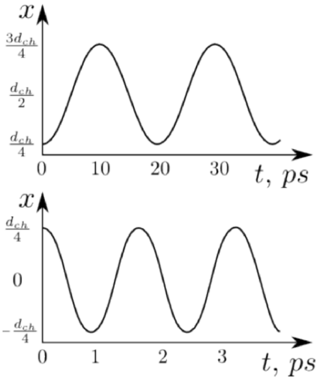


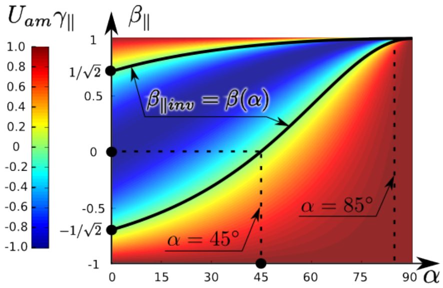
Figure : a) Potential amplitude as a function of α and β; b) same for counter-propagating laser beams ($\alpha = 0$).

Inversion


A.L. Pokrovsky
and A.E. Kaplan
A
π/2
θ
η
ξ
2.5
2.0
1.5
1.0
0.5
0.0
-300 -200 -100 0 100 200 300
1.0
0.5
0.0
-0.5
-1.0

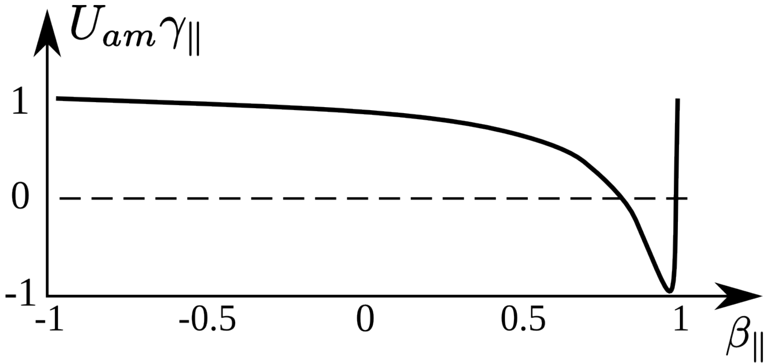

x
$\frac{3d_{ch}}{4}$
$\frac{d_{ch}}{2}$
$\frac{d_{ch}}{4}$
0 10 20 30 $t,\ ps$
x
$\frac{d_{ch}}{4}$
0
$-\frac{d_{ch}}{4}$
0 1 2 3 $t,\ ps$

P-polarized beams potential. Inversion speed

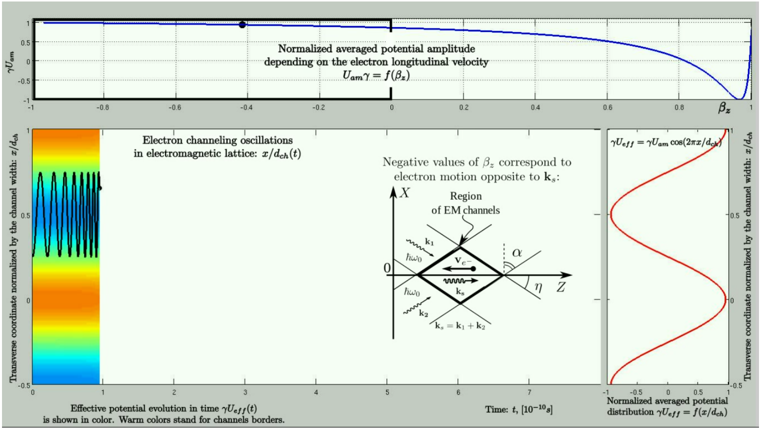


$$\beta_{\|inv}(\alpha) = \frac{\sin\alpha \pm \cos\alpha\sqrt{[1+\cos(2\alpha)]}}{1+\cos^2\alpha}$$

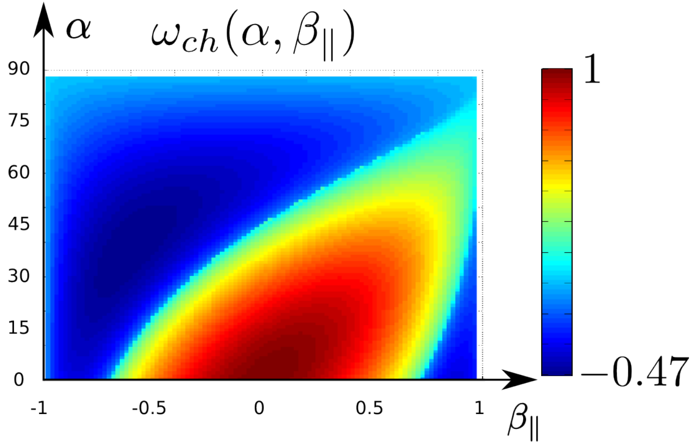
Normalized potential amplitude for $\alpha = 85^\circ$



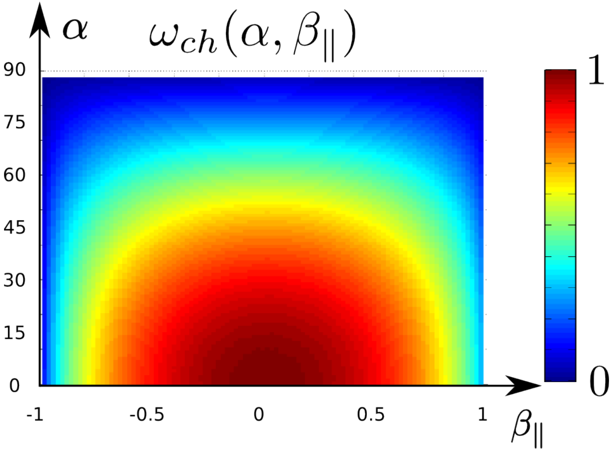
Time to see the movie



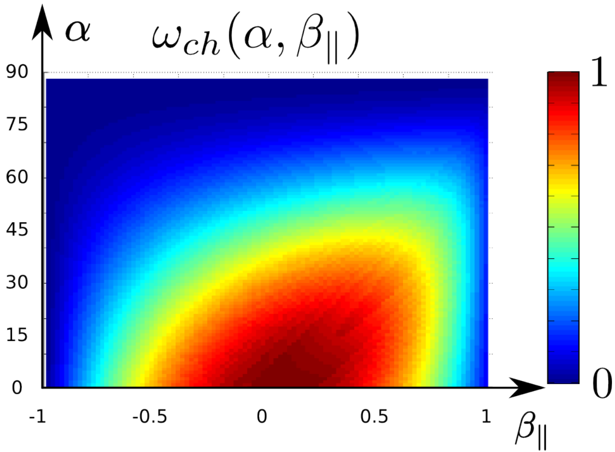
P-polarized laser beams



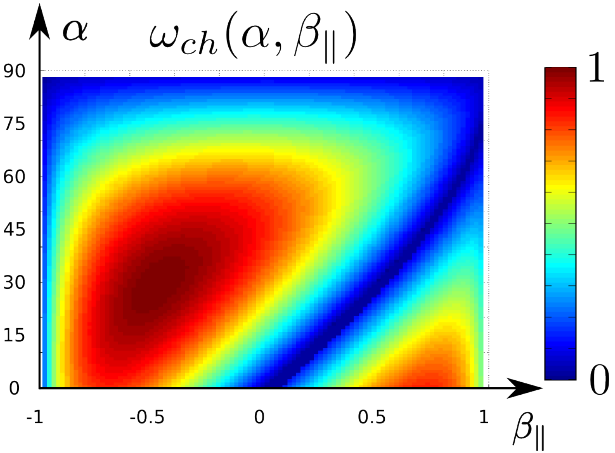
S-polarized laser beams



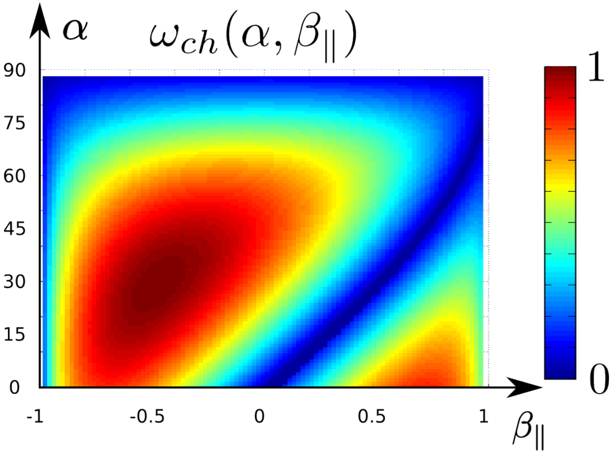
Diagonal lasers polarization



Circular polarization. Both rotating left (or right)



Circular polarization. One — left, one — right. Preliminary.



Circular polarization channeling frequency

$$\omega = \frac{\sqrt{2}eA_0k^2}{\gamma_{||}m_e\omega_0}\frac{\cos\alpha\sqrt{[1+2\beta_{||}^2 - cos(2\alpha) - 4\beta_{||}\sin\alpha]}}{1-\beta_{||}\sin\alpha}$$

Summary

- Electron channeling in the field of two crossed laser beams is now extensively described
- Potential geometry, magnitude and channeling oscillations frequency is described for all electron energies
- and laser beams polarization
- and **now** crossing angles
- Classical channeling radiation for such a system is not a problem also

What next

- Dynamics description in terms of quantum mechanics
- Electron deflection by curved laser fields description
- Taking account of radiation losses
- **The experiment proposal**

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