

ISSN: 0256-307X

中国物理快报

Chinese Physics Letters

Volume 28 Number 7 July 2011

A Series Journal of the Chinese Physical Society
Distributed by IOP Publishing

Online: <http://iopscience.iop.org/cpl>
<http://cpl.iphy.ac.cn>

CHINESE PHYSICAL SOCIETY
Institute of **Physics** PUBLISHING

JOURNAL FOR AUTHORS
— CHINESE PHYSICS LETTERS

Magic Wavelength of an Optical Clock Transition of Barium *

YU Geng-Hua(余庚华)^{1,2,3}, ZHONG Jia-Qi(仲嘉琪)^{1,2,3}, LI Run-Bing(李润兵)^{1,2}, WANG Jin(王谨)^{1,2}, ZHAN Ming-Sheng(詹明生)^{1,2**}

¹ State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, Wuhan 430071

² Center for Cold Atom Physics, Chinese Academy of Sciences, Wuhan 430071

³ Graduate University, Chinese Academy of Sciences, Beijing 100049

(Received 30 March 2011)

Similar to most of the other alkaline earth elements, barium atoms can be candidates for optical clocks, thus the magic wavelength for an optical lattice is important for the clock transition. We calculate the magic wavelength of a possible clock transition between $6s^2\ ^1S_0$ and $6s5d\ ^3D_2$ states of barium atoms. Our theoretical result shows that there are three magic wavelengths 615.9 nm, 641.2 nm and 678.8 nm for a linearly polarized optical lattice laser for barium.

PACS: 32.60.+i, 37.10.Jk, 32.70.Jz

DOI:10.1088/0256-307X/28/7/073201

Optical clocks based on neutral atoms have attracted great attention due to their variable applications. Possible applications include next-generation frequency standards, new tests of fundamental physics, more accurate measurements of fundamental constants and their time dependence, and further improvement in global positioning systems.^[1–4] Optical lattice traps formed by a far off-resonant laser are very useful for confining cold atoms. Collision shift and broadening of atoms confined in optical lattices can be effectively eliminated. In addition, when atoms are confined to a Lamb–Dicke region, the first-order Doppler shift will vanish.^[5,6]

For high precision frequency standards, light shift of the clock transitions caused by a trapping laser needs to be avoided. Thus the wavelength of the trapping light should be tuned to a region where the light shifts of two states of the clock transition cancel each other. This special wavelength is called the magic wavelength. Katori *et al.*^[7–9] have proposed to utilize optical lattice traps formed with a magic wavelength trapping laser, and this ingenious technique can greatly improve the established high-accuracy optical frequency standard based on neutral atoms. Optical lattice clocks of alkaline-earth atom Sr and rare-earth atom Yb have been widely studied and have achieved great success in recent years.^[10–13] Alkaline-earth metal Ba has a very sharp optical transition $6s^2\ ^1S_0$ – $6s5d\ ^3D_2$ with a lifetime of about 69 s^[14] of the upper level. The natural linewidth of this clock transition is about 2 mHz, thus Ba can also be a good candidate for an optical frequency standard. The cooling and trapping of barium atoms has been realized and reported in Ref. [15], which makes it possible for

us to build an accurate optical clock based on barium atoms trapped in an optical lattice. In this Letter, we propose to use the Ba $6s^2\ ^1S_0$ – $6s5d\ ^3D_2$ transition as a clock transition and present a calculation of magic wavelength for this clock.

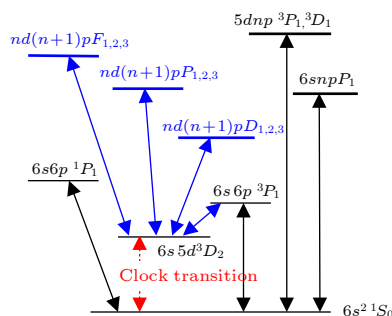


Fig. 1. Diagram of the energy levels for barium atoms and some possible laser couplings.

Calculation of energy shift caused by the trapping laser has been reported before.^[16–19] According to second-order perturbation theory, when atoms are in state $|i\rangle$ with energy E_i and Zeeman sublevel m_i , emerged in a trapping laser field with frequency $\nu = \omega/2\pi$, polarization p , and intensity I , the energy shift of the atomic state, $U_i(\omega, p, m_i)$, can be expressed as

$$U_i(\omega, p, m_i) = -\frac{\alpha_i(\omega, p, m_i)I}{2\varepsilon_0 c}, \quad (1)$$

where $\alpha_i(\omega, p, m_i)$ is the induced polarizability, which can be calculated by summation over the contributions coming from all dipole transitions from the desired level i to all other levels k with the respective Einstein coefficients A_{ki} (spontaneous emission rate for $E_k > E_i$), Zeeman sublevels m' and transition fre-

*Supported by the National Natural Science Foundation of China under Grant Nos 11004227 and 11074281, the National Basic Research Program of China under Grant No 2010CB832805, and the Chinese Academy of Sciences.

**To whom correspondence should be addressed. Email: mszhan@wipm.ac.cn

© 2011 Chinese Physical Society and IOP Publishing Ltd

quencies $v_{ik} = \omega_{ik}/2\pi$,

$$\alpha_i = 6\pi c^3 \varepsilon_0 \sum_{k,m'} \frac{A_{ki}(2J_k + 1)}{\omega_{ik}^2(\omega_{ik}^2 - \omega^2)} \begin{pmatrix} J_i & 1 & J_k \\ m_i & p & -m' \end{pmatrix}^2. \quad (2)$$

The expression in large parentheses denotes a $3J$ symbol. If we know ω_{ik} and A_{ki} in Eq. (2), we can obtain the polarizability α_i .

For barium atoms, the energy diagram can be sim-

plified, as shown in Fig. 1. Here, 1S_0 is the ground state and 3D_2 is the metastable triplet state with a lifetime of about 69 s.

Table 1 shows the wave numbers (WN) and probabilities (Einstein coefficients A_{ki}) of transitions originating from the $6s^2^1S_0$ and $6s5d^3D_2$ states of barium. We choose the available experimental values as much as possible from Refs. [20,21], then we take part of the theoretical data from Ref. [22], and for the rest we mainly use the values in Ref. [23].

Table 1. Atom transition data of barium.

Lower state $ i\rangle$	Upper state $ k\rangle$	WN (cm^{-1})	A_{ki} (10^6s^{-1})	References
$6s5d^3D_2$ (9215.501 cm^{-1})	$6s7p^1P_1$	32547.033	0.38	[22]
	$6s7p^3P_2$	30987.240	2.1	[22]
	$6s7p^3P_1$	30815.512	8.6	[22]
	$5d6p^1P_1$	28554.221	0.090	[21]
	$5d6p^1F_3$	26 816.266	0.34	[22]
	$5d6p^3P_2$	25956.519	16.2	[21]
	$5d6p^3P_1$	25704.110	56.0	[20]
	$5d6p^3D_3$	24979.834	11.6	[21]
	$5d6p^3D_2$	24531.513	33.0	[20]
	$5d6p^3D_1$	24192.033	18.9	[20]
	$5d6p^1D_2$	23074.387	0.065	[21]
	$5d6p^3F_3$	22947.423	32.0	[20]
	$5d6p^3F_2$	22064.645	7.6	[20]
	$6s6p^1P_1$	18060.261	0.11	[20]
	$6s6p^3P_2$	13514.745	0.1	[22]
	$6s6p^3P_1$	12636.623	0.32	[23]
$6s^2^1S_0$ (ground state)	$6s18p^1P_1$	41494.39	0.086	[20]
	$6s17p^1P_1$	41411.04	0.15	[20]
	$6s16p^1P_1$	41307.88	0.23	[20]
	$6s15p^1P_1$	41183.60	0.56	[20]
	$5d8p^3P_1$	41097.20	0.72	[20]
	$6s14p^1P_1$	40991.23	0.14	[20]
	$5d8p^3D_1$	40893.76	0.45	[20]
	$6s13p^1P_1$	40765.23	0.081	[20]
	$6s12p^1P_1$	40428.68	0.46	[20]
	$6s11p^1P_1$	39982.14	1.5	[20]
	$6s10p^1P_1$	39311.95	0.041	[20]
	$5d7p^1P_1$	38499.86		[20]
	$6s9p^1P_1$	37775.28	1.1	[20]
	$5d7p^3P_1$	36989.98		[20]
	$5d7p^3D_1$	36495.732		[20]
	$6s8p^1P_1$	35892.465		[20]
	$6s7p^1P_1$	32547.033	42.0	[20]
	$6s7p^3P_1$	30815.512	0.013	[20,22]
	$5d6p^1P_1$	28554.221	35.0	[20]
	$5d6p^3P_1$	25704.110	1.1	[20]
$5d6p^3D_1$	24192.033	1.5	[20]	
$6s6p^1P_1$	18060.261	119	[20]	
$6s6p^3P_1$	12636.623	0.299	[23]	

We now calculate the light shift for $m = 0$ levels of the optical clock transition from $6s^2^1S_0$ to $6s5d^3D_2$ of a boson barium isotope with nuclear spin of $I = 0$. The magic wavelength is the wavelength of the trapping laser where the light shifts of the two states for a corresponding transition are the same. For the $6s^2^1S_0$ - $6s5d^3D_2$ clock transition of barium atoms

considered in this work, the magic wavelength value corresponds to the crossing of the light shift curves for the $6s^2^1S_0$ and $6s5d^3D_2$ states.

Figure 2 displays the dependence of energy level shift difference for barium on wavelength of a linearly polarized trapping laser. The light shift is defined as U/h (U is the energy shift of a state), and the inten-

sity of the trapping laser is $1 \times 10^4 \text{ W/cm}^2$. As shown by the arrows in Fig. 2, at 615.9 nm, 641.2 nm, and 678.8 nm the states 1S_0 and 3D_2 have the same light shifts. Thus these wavelengths are magic wavelengths for the Ba clock.

We also consider the magic wavelength caused by a circularly polarized laser. The light shifts caused by linearly polarized and circularly polarized lasers with wavelengths around 615 nm, 640 nm and 680 nm are presented in Figs. 3(a), 3(b) and 3(c), respectively. The vertical axis ΔU is defined as $\Delta U = U_{3D_2} - U_{1S_0}$, which shows the light shift difference of the two energy levels. The magic wavelength occurs at a point where $\Delta U = 0$. It is found that the new magic wavelengths are 609.3 nm, 636.6 nm and 679.8 nm in the case of a circularly polarized laser field. From Fig. 3(c) we can see that the light shifts caused by linearly and circularly polarized lasers around 680 nm are much closer than other wavelengths.

Now we consider a one-dimensional optical lattice consisting of a partially polarized laser, assuming that the circularly polarized laser intensity is 1/3 of the total laser intensity. The total light shift caused by this trapping laser is the sum of 2/3 of the shift of a linearly polarized laser and 1/3 of the shift of a circularly polarized laser. Then the magic wavelengths of 615.9 nm, 641.2 nm and 678.8 nm should be moved to 613.8 nm, 638.8 nm and 679.0 nm, respectively, according to the polarization of the perturbing laser. Other portions of circularly polarized laser light in one-dimensional or two-dimensional optical lattices can be calculated in the same way and we give some modification to the magic wavelengths.

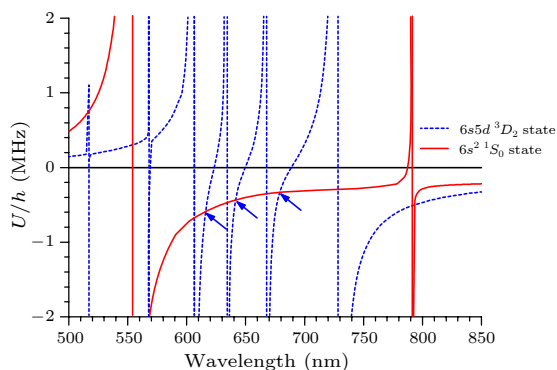


Fig. 2. Dependence of energy level shifts of barium atoms in the ground and $6s5d^3D_2$ ($m=0$) states on a linearly polarized trapping laser wavelength. The arrows show the magic wavelength points.

We can also estimate the trap depth of the optical lattice and the slope of the light shift with a linearly polarized laser. The trap depth of the optical lattice at a magic wavelength with a laser intensity of 10^4 W/cm^2 is defined as the maximum temperature of the trapped atoms $T = U/k_B$ (k_B is

Boltzmann's constant). The slope of light shift difference at a magic wavelength defined as $k = \frac{d}{d\lambda}(\Delta U)$ ($\Delta U = U_{3D_2} - U_{1S_0}$) shows how fast the difference changes with the laser wavelength. These are listed in Table 2.

Table 2. Trap depth and light shift slope at different magic wavelengths.

λ_{magic} (nm)	Trap depth (μK)	K (MHz/nm)
615.9	29.1	0.11
641.2	22.1	0.09
678.8	16.8	0.05

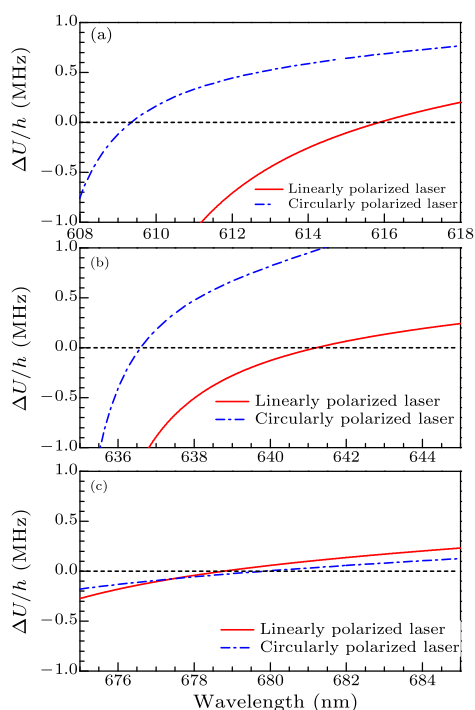


Fig. 3. Difference in light shifts caused by linearly polarized and circularly polarized lasers around (a) 615 nm, (b) 640 nm and (c) 680 nm. The new magic wavelengths occur at 609.3 nm, 636.6 nm and 679.8 nm for a circularly polarized laser field, compared with the previous magic wavelengths of 615.9 nm, 641.2 nm and 678.8 nm, respectively, for a linearly polarized laser. In the calculation, the laser intensity of $1 \times 10^4 \text{ W/cm}^2$ is used.

Based on the calculation and the availability of current commercial lasers, we recommend 678.8 nm as the laser wavelength for optical trapping, because the influence due to possible circularly polarized light is minimal in comparison to the other two wavelengths, 615.9 nm and 641.2 nm. The shift slope is also smaller and the trap depth is deep enough to trap barium atoms.

In summary, we have calculated the magic wavelength for $6s^2 1S_0$ to $6s5d^3D_2$ clock transition ($m=0$) of boson isotope barium with $I=0$, and we have analyzed and compared the magic wavelengths caused by linearly polarized and circularly polarized lasers. We recommend 678.8 nm as a magic wavelength for an op-

tical lattice laser. This result is helpful for building an optical clock with barium in an optical lattice.

References

- [1] Hong F L, Takamoto M, Higashi R, Fukuyama Y, Jiang J and Katori H 2005 *Opt. Express* **13** 5253
- [2] Ido T, Loftus T H, Boyd M M, Ludlow A D, Holman K W, and Ye J 2005 *Phys. Rev. Lett.* **94** 153001
- [3] Marion H, Pereira D S F, Abgrall M, Zhang S, Sortais Y, Bize S, Maksimovic I, Calonico D, Grünert J, Mandache C, Lemonde P, Santarelli G, Laurent Ph and Clairon A 2003 *Phys. Rev. Lett.* **90** 150801
- [4] Bauch A 2003 *Meas. Sci. Technol.* **14** 1159
- [5] Friebe J, Pape A, Riedmann M, Moldenhauer K, Mehlstaubler T, Rehbein N, Lisdat C, Rasel E M, Ertmer W, Schnatz H, Lipphardt B and Grosche G 2008 *Phys. Rev. A* **78** 033830
- [6] Zhou X J, Chen X Z, Chen J B, Wang Y Q and Li J M 2009 *Chin. Phys. Lett.* **26** 090601
- [7] Katori H, Ido T and Kuwata-Gonokami M 1999 *J. Phys. Soc. Jpn.* **68** 2479
- [8] Katori H, Takamoto M, Pal'chikov V G and Ovsinnikov V D 2003 *Phys. Rev. Lett.* **91** 173005
- [9] Takamoto M, Hong F L, Higashi R and Katori H 2005 *Nature* **435** 321
- [10] Barber Z W, Hoyt C W, Oates C W, Hollberg L, Taichenachev A V and Yudin V I 2006 *Phys. Rev. Lett.* **96** 083002
- [11] Le Targat R, Baillard X, Fouche' M, Brusca A, Tcherbakoff O, Rovera G D and Lemonde P 2006 *Phys. Rev. Lett.* **97** 130801
- [12] Lodewyck J, Westergaard P G and Lemonde P 2009 *Phys. Rev. A* **79** 061401
- [13] Lisdat Ch, Vellere Winfred J S R, Middelmann T, Riehle F and Sterr U 2009 *Phys. Rev. Lett.* **103** 090801
- [14] Dzuba V A and Ginges J S M 2006 *Phys. Rev. A* **73** 032503
- [15] De S, Dammalapati U, Jungmann K and Willmann L 2009 *Phys. Rev. A* **79** 041402
- [16] Degenhardt C, Stoehr H, Sterr U, Riehle F and Lisdat C 2004 *Phys. Rev. A* **70** 023414
- [17] Grimm R, Weidemuller M and Ovchinnikov Y B 2000 *Adv. At. Mol. Opt. Phys.* **42** 95
- [18] Zhou X J, Xu X, Chen X Z and Chen J B 2010 *Phys. Rev. A* **81** 012115
- [19] Zheng Y N, Zhou X J, Chen J B and Chen X Z 2006 *Chin. Phys. Lett.* **23** 1687
- [20] Ralchenko Y, Kramida A E, Reader J and NIST ASD Team (2010). *NIST Atomic Spectra Database* (ver. 4.0.1) (Gaithersburg, MD: National Institute of Standards and Technology) <http://physics.nist.gov/asd>
- [21] Klose J Z, Fuhr J R and Wiese W L 2002 *J. Phys. Chem. Ref. Data* **31** 217
- [22] Kulaga D, Migdalek J and Bar O 2001 *J. Phys. B: At. Mol. Opt. Phys.* **34** 4775
- [23] Brust J and Gallagher A C 1995 *Phys. Rev. A* **52** 2120

Chinese Physics Letters

Volume 28

Number 7

July 2011

GENERAL

- 070201 Two New Fourth-Order Three-Stage Symplectic Integrators**
LI Rong, WU Xin
- 070202 Quantum Stackelberg Duopoly in a Noninertial Frame**
Salman Khan, M. Khalid Khan
- 070203 Numerical Simulation of Hyperbolic Gradient Flow with Pressure**
LI Dong, XIE Zheng, YI Dong-Yun
- 070204 Coevolution of Structure and Strategy Promoting Fairness in the Ultimatum Game**
DENG Li-Li, TANG Wan-Sheng, ZHANG Jian-Xiong
- 070301 A Probability Measure for Entanglement of Pure Two-Qubit Systems and a Useful Interpretation for Concurrence**
Abbass Sabour, Mojtaba Jafarpour
- 070302 Photon Counting Optical Time Domain Reflectometry Applying a Single Photon Modulation Technique**
WANG Xiao-Bo, WANG Jing-Jing, HE Bo, XIAO Lian-Tuan, JIA Suo-Tang
- 070303 Energy Spectra of the Harmonic Oscillator in a Generalized Noncommutative Phase Space of Arbitrary Dimension**
LIN Bing-Sheng, HENG Tai-Hua
- 070304 Feasibility of Double-Click Attack on a Passive Detection Quantum Key Distribution System**
ZHANG Peng, LI Chao
- 070305 Quantum Computing via Singlet-Triplet Spin Qubits in Nanowire Double Quantum Dots**
XUE Peng
- 070306 Quantum Discord Dynamics of Two Atoms Interacting with Two Quantized Field Modes through a Raman Interaction with Phase Decoherence**
QIAN Yi, XU Jing-Bo
- 070307 Efficient Phase-Encoding Quantum Key Generation with Narrow-Band Single Photons**
YAN Hui, ZHU Shi-Liang, DU Sheng-Wang
- 070308 Experimental Demonstration of Largeness in Bipartite Entanglement Sudden Death**
PENG Liang, HUANG Yun-Feng, LI Li, LIU Bi-Heng, LI Chuan-Feng, GUO Guang-Can
- 070401 Measurement of the Speed of Gravity**
ZHU Yin
- 070402 Chaos in Kundt Type-III Spacetimes**
I. Sakalli, M. Halilsoy
- 070403 Generalized Second Law of Thermodynamics in Wormhole Geometry with Logarithmic Correction**
Faiz-ur-Rahman, Salahuddin, M. Akbar
- 070501 Ground-State Density Profiles of One-Dimensional Bose Gases with Anisotropic Transversal Confinement**
HAO Ya-Jiang
- 070701 Enhanced Total Ionizing Dose Susceptibility in Narrow Channel Devices**
LIU Zhang-Li, HU Zhi-Yuan, ZHANG Zheng-Xuan, SHAO Hua, NING Bing-Xu, BI Da-Wei, CHEN Ming, ZOU Shi-Chang
- 070702 Micro Humidity Sensor with High Sensitivity and Quick Response/Recovery Based on ZnO/TiO₂ Composite Nanofibers**
XU Lei, WANG Rui, XIAO Qi, ZHANG Dan, LIU Yong

JUST FOR AUTHORS
— CHINESE PHYSICS LETTERS

- 070703 AMS Measurement of ^{53}Mn at CIAE**
DONG Ke-Jun, HE Ming, LI Chao-Li, HU Hao, LIU Guang-Shan, CHEN Zhi-Gang, LI Zhen-Yu, WU Shao-Yong, LIU Jian-Cheng, YOU Qu-Bo, JIN Chun-Sheng, WANG Xiang-Gao, SHEN Hong-Tao, GUAN Yong-Jing, YUAN Jian, JIANG Shan

THE PHYSICS OF ELEMENTARY PARTICLES AND FIELDS

- 071101 Hamiltonian of Green–Schwarz IIB Superstring Theory in $AdS_3 \times S^3$ Background**
KE San-Min, WANG Chun, WANG Zhan-Yun, JIANG Ke-Xia, SHI Kang-Jie
- 071201 A Primary Study of Heavy Baryons $\Lambda_Q, \Sigma_Q, \Xi_Q$ and Ω_Q**
ZHAO Qiao-Yan, ZHANG Dan, ZHANG Qiu-Yang
- 071301 The Decay Rate of J/ψ to $\Lambda_c + \overline{\Sigma}^+$ in and beyond the Standard Model**
KE Hong-Wei, CHEN Ya-Zheng, LI Xue-Qian

NUCLEAR PHYSICS

- 072601 Cooling of Hyperonic Neutron Stars with Antikaons**
DING Wen-Bo, YU Zi, LIU Yu-Hui
- 072901 Power Test of the Ladder IH-RFQ Accelerator at Peking University**
LU Yuan-Rong, CHEN Wei, NIE Yuan-Cun, LIU Ge, GAO Shu-Li, ZENG Hong-Jin, YAN Xue-Qing, CHEN Jia-Er

ATOMIC AND MOLECULAR PHYSICS

- 073201 Magic Wavelength of an Optical Clock Transition of Barium**
YU Geng-Hua, ZHONG Jia-Qi, LI Run-Bing, WANG Jin, ZHAN Ming-Sheng
- 073202 Laser-Focused Atomic Deposition for Nanoscale Grating**
MA Yan, LI Tong-Bao, WU Wen, XIAO Yi-Li, ZHANG Ping-Ping, GONG Wei-Gang
- 073301 Analytical Research on Rotation-Vibration Multiphoton Absorption of Diatomic Molecules in Infrared Laser Fields**
FENG Hai-Ran, CHENG Jie, YUE Xian-Fang, ZHENG Yu-Jun, DING Shi-Liang
- 073302 Water Vapor Interference Correction in a Non Dispersive Infrared Multi-Gas Analyzer**
SUN You-Wen, LIU Wen-Qing, ZENG Yi, WANG Shi-Mei, HUANG Shu-Hua, XIE Pin-Hua, YU Xiao-Man
- 073401 Integral and Momentum Cross Sections for Electron Elastic and Vibrational Excitation Scattering with Nitrogen in the Energy Range 5–30 eV**
ZENG Yang-Yang, FENG Hao, SUN Wei-Guo
- 073701 An Optimum Method for a Grooved 2D Planar Ion Trap Design**
JI Wei-Bang, WAN Jin-Yin, CHENG Hua-Dong, LIU Liang

FUNDAMENTAL AREAS OF PHENOMENOLOGY(INCLUDING APPLICATIONS)

- 074101 An Approximate Analytical Propagation Formula for Gaussian Beams through a Cat-Eye Optical Lens under Large Incidence Angle Condition**
ZHAO Yan-Zhong, SUN Hua-Yan, ZHENG Yong-Hui
- 074201 An All-Fiber Gas Raman Light Source Based on a Hydrogen-Filled Hollow-Core Photonic Crystal Fiber Pumped with a Q-Switched Fiber Laser**
CHEN Xiao-Dong, MAO Qing-He, SUN Qing, ZHAO Jia-Sheng, LI Pan, FENG Su-Juan
- 074202 A Compact and Highly Efficient Silicon-Based Asymmetric Mach–Zehnder Modulator with Broadband Spectral Operation**
ZHOU Liang, LI Zhi-Yong, XIAO Xi, XU Hai-Hua, FAN Zhong-Chao, HAN Wei-Hua, YU Yu-De, YU Jin-Zhong
- 074203 Room-Temperature Continuous-Wave Operation of a Tunable External Cavity Quantum Cascade Laser**
ZHANG Jin-Chuan, WANG Li-Jun, LIU Wan-Feng, LIU Feng-Qi, YIN Wen, LIU Jun-Qi, LI Lu, WANG Zhan-Guo

- 074204 An Optical 2×4 90° Hybrid Based on a Birefringent Crystal for a Coherent Receiver in a Free-Space Optical Communication System**
HOU Pei-Pei, ZHI Ya-Nan, ZHOU Yu, SUN Jian-Feng, LIU Li-Ren
- 074205 Laser Cleaning Techniques for Removing Surface Particulate Contaminants on Sol-Gel SiO_2 Films**
ZHANG Chun-Lai, LI Xi-Bin, WANG Zhi-Guo, LIU Chun-Ming, XIANG Xia, LV Hai-Bing, YUAN Xiao-Dong, ZU Xiao-Tao
- 074206 Complex Spectra Structure of an Attosecond Pulse Train Driven by Sub-5-fs Laser Pulses**
YUN Chen-Xia, TENG Hao, ZHANG Wei, WANG Li-Feng, ZHAN Min-Jie, HE Xin-Kui, WANG Bing-Bing, WEI Zhi-Yi
- 074207 A Special Sampling Structure with an Arbitrary Equivalent-Phase-Shift for Semiconductor Lasers and Multiwavelength Laser Arrays**
ZHOU Ya-Ting, SHI Yue-Chun, LI Si-Min, LIU Sheng-Chun, CHEN Xiang-Fei
- 074208 High-Efficiency Supercontinuum Generation at 12.8 W in an All-Fiber Device**
WANG Yan-Bin, HOU Jing, CHEN Zi-Lun, CHEN Sheng-Ping, SONG Rui, LI Ying, YANG Wei-Qiang, LU Qi-Sheng
- 074209 Voltage-Controlled Scattering of Single Photons in a One-Dimensional Waveguide**
LUO Ya-Qin, SONG Yan-Yan, GU Ling-Ming, LANG Jia-Hong, MA Xiao-San
- 074210 Acousto-Optic Q-Switched Operation Ho:YAP Laser Pumped by a Tm-Doped Fiber Laser**
ZHOU Ren-Lai, JU You-Lun, WANG Wei, ZHU Guo-Li, WANG Yue-Zhu
- 074211 Noise Suppression of a Single Frequency Fiber Laser**
LIU Kui, CUI Shu-Zhen, ZHANG Hai-Long, ZHANG Jun-Xiang, GAO Jiang-Rui
- 074212 Spectrum Analysis of a Pulsed Photon Source Generated from Periodically Poled Lithium Niobate**
FANG Bin, LIU Bi-Heng, HUANG Yun-Feng, SHI Bao-Sen, GUO Guang-Can
- 074213 Dipole Solitons in Nonlinear Media with an Exponential-Decay Nonlocal Response**
YANG Zhen-Jun, MA Xue-Kai, ZHENG Yi-Zhou, GAO Xing-Hui, LU Da-Quan, HU Wei
- 074214 Narrowband Biphoton Generation with Four-Wave Mixing in a Far-Detuning Three-Level System**
CHEN Peng, ZHOU Shu-Yu, XU Zhen, DUAN Ya-Fan, CUI Guo-Dong, HONG Tao, WANG Yu-Zhu
- 074215 Two Schemes for Generating Efficient Terahertz Waves in Nonlinear Optical Crystals with a Mid-Infrared CO_2 Laser**
RAO Zhi-Ming, WANG Xin-Bing, LU Yan-Zhao, ZUO Du-Luo, WU Tao
- 074216 Photocurrent Effect in Reverse-Biased p-n Silicon Waveguides in Communication Bands**
ZHAO Yong, XU Chao, WANG Wan-Jun, ZHOU Qiang, HAO Yin-Lei, YANG Jian-Yi, WANG Ming-Hua, JIANG Xiao-Qing
- 074217 Nonadiabatic Effects of Atomic Coherence on Laser Intensity Fluctuations in Electromagnetically Induced Transparency**
XU Qing, HU Xiang-Ming
- 074218 Broadband Response of Second Harmonic Generation in a Two-Dimensional Quasi-Random Quasi-Phase-Matching Structure**
MA Dong-Li, REN Ming-Liang, LI Zhi-Yuan
- 074219 Tolerance on Tilt Error for the Incoherent Combination of Fiber Lasers in a Real Environment**
TAO Ru-Mao, SI Lei, MA Yan-Xing, ZOU Yong-Chao, ZHOU Pu
- 074220 Kerr-Lens Self-Mode-Locked Laser Characteristics of Yb: Lu_2SiO_5 Crystal**
LIU Jie, YANG Ji-Min, WANG Wei-Wei, ZHENG Li-He, SU Liang-Bi, XU Jun
- 074301 Time-Domain Second-Harmonic Generation of Primary Lamb-Wave Propagation in an Elastic Plate**
DENG Ming-Xi, XIANG Yan-Xun, LIU Liang-Bing
- 074701 Boundary Layer Flow and Heat Transfer over an Exponentially Shrinking Sheet**
Krishnendu Bhattacharyya

074702 Simultaneous Effects of MHD and Thermal Radiation on the Mixed Convection Stagnation-Point Flow of a Power-Law Fluid
T. Hayat, M. Mustafa, S. Obaidat

PHYSICS OF GASES, PLASMAS, AND ELECTRIC DISCHARGES

075201 Emission Lines of Boron, Carbon, Oxygen and Iron in Tokamak Plasma

DI Long, SHI Jian-Rong, WANG Shou-Jun, DONG Quan-Li, ZHAO Jing, LI Yu-Tong, FU Jia, WANG Fu-Di, SHI Yue-Jiang, WAN Bao-Nian, ZHAO Gang, ZHANG Jie

075202 Nonlinear Plasma Dynamics in Electron Heating of Asymmetric Capacitive Discharges with a Fluid Sheath Model

DAI Zhong-Ling, WANG You-Nian

075203 Dust Acoustic Rotation Modes in Magnetized Complex Plasmas

B. Farokhi, F. Amini, M. Eghbali

075204 Role of Jeans Instability in Multi-Component Quantum Plasmas in the Presence of Fermi Pressure

S. Ali Shan, A. Mushtaq

075205 A Modified Third-Order Semi-Discrete Central-Upwind Scheme for MHD Simulation

JI Zhen, ZHOU Yu-Fen, HOU Tian-Xiang

075206 Strong Coupling between Propagating and Localized Surface Plasmons in Plasmonic Cavities

LI Ming-Zhu, AN Zheng-Hua, ZHOU Lei, MAO Fei-Long, WANG Heng-Liang

CONDENSED MATTER: STRUCTURE, MECHANICAL AND THERMAL PROPERTIES

076101 High Pressure X-Ray Diffraction Study of a Grossular–Andradite Solid Solution and the Bulk Modulus Variation along this Solid Solution

FAN Da-Wei, WEI Shu-Yi, LIU Jing, LI Yan-Chun, XIE Hong-Sen

076102 Theoretical Hardness of Zr_3N_4 Films

GAO Fa-Ming

076201 High-Order Elastic Constants and Anharmonic Properties of $NaBH_4$: First-Principles Calculations

ZHANG Xiao-Dong, JIANG Zhen-Yi, ZHOU Bo, HOU Zhu-Feng, HOU Yu-Qing

076801 Anisotropic Diffusion Evolution of Vacancies Created by Oxygen Etching on a Si Surface

WANG Shu-Hua, CAI Qun

076802 Scanning Tunneling Spectroscopy of Metal Phthalocyanines on a Au(111) Surface with a Ni Tip

JIA Zhi-Chun, HU Zhen-Peng, ZHAO Ai-Di, LI Zhen-Yu, LI Bin

076803 Growth of Graphene Nanoribbons and Carbon Onions from Polymer

GUO Xiao-Song, LU Bing-An, XIE Er-Qing

CONDENSED MATTER: ELECTRONIC STRUCTURE, ELECTRICAL, MAGNETIC, AND OPTICAL PROPERTIES

077101 Electronic Structure and Optical Properties of $SrBi_2A_2O_9$ ($A=Nb, Ta$)

ZHAO Na, WANG Yue-Hua, ZHAO Xin-Yin, ZHANG Min, GONG Sai

077102 Effects of an Intense Laser Field and Hydrostatic Pressure on the Intersubband Transitions and Binding Energy of Shallow Donor Impurities in a Quantum Well

U. Yesilgul, F. Ungan, E. Kasapoglu, H. Sari, I. Sökmen

077103 Zener Tunneling in One-Dimensional Organic Semiconductors at Finite Temperature

LIU Wen, CHENG Jie, ZHANG Ming-Hua, LIU De-Sheng

077201 CMOS Compatible Nonvolatile Memory Devices Based on $SiO_2/Cu/SiO_2$ Multilayer Films

WANG Yan, LIU Qi, LV Hang-Bing, LONG Shi-Bing, ZHANG Sen, LI Ying-Tao, LIAN Wen-Tai, YANG Jian-Hong, LIU Ming

JUST FOR SCIENTISTS
— CHEMISTS PHYSICISTS ENGINEERS

- 077202 Enhancement-Mode AlGa_N/Ga_N High Electron Mobility Transistors Using a Nano-Channel Array Structure**
LIU Sheng-Hou, CAI Yong, GONG Ru-Min, WANG Jin-Yan, ZENG Chun-Hong, SHI Wen-Hua, FENG Zhi-Hong, WANG Jing-Jing, YIN Jia-Yun, Cheng P. Wen, QIN Hua, ZHANG Bao-Shun
- 077301 Crystalline, Optical and Electrical Properties of NiZnO Thin Films Fabricated by MOCVD**
WANG Jin, WANG Hui, ZHAO Wang, MA Yan, LI Wan-Cheng, XIA Xiao-Chuan, SHI Zhi-Feng, ZHAO Long, ZHANG Bao-Lin, DONG Xin, DU Guo-Tong
- 077501 Magnetostrictions and Magnetic Properties of Nd-Fe-B and SrFe₁₂O₁₉**
CHEN Hai-Ying, ZHANG Yan, YANG Yun-Bo, CHEN Xue-Gang, LIU Shun-Quan, WANG Chang-Sheng, YANG Ying-Chang, YANG Jin-Bo
- 077701 Peripheral Ferroelectric Domain Switching and Polarization Fatigue in Nonvolatile Memory Elements of Continuous Pt/SrBi₂Ta₂O₉/Pt Thin-Film Capacitors**
CHEN Min-Chuan, JIANG An-Quan
- 077702 Sol-Gel Template Synthesis and Photoluminescence Properties of (Pb_{0.5}Sr_{0.5})TiO₃ Nanotube Arrays**
JIANG Yan-Ping, WANG Yu, CHAN Lai Wa Helen, TANG Xin-Gui, ZHOU Yi-Chun
- 077801 Photo- and Electro-Luminescence at 1.54 μm from Er³⁺ in SiC:Er₂O₃ Films and Structures**
YIN Yang, RAN Guang-Zhao, ZHANG Bin, QIN Guo-Gang
- 077802 Bias Effects on the Growth of Helium-Containing Titanium Films**
ZHANG Li-Ran, DENG Ai-Hong, YANG Dong-Xu, ZHOU Yu-Lu, HOU Qing, SHI Li-Qun, ZHONG Yu-Rong, WANG Bao-Yi
- 077803 Infrared Luminescent Properties of a Pr-Doped KBr Submicron Rod**
WEI Feng-Wei, ZHANG Xiao-Song, LI Lan, XU Jian-Ping, ZHOU Yong-Liang, LIU Pei
- CROSS-DISCIPLINARY PHYSICS AND RELATED AREAS OF SCIENCE AND TECHNOLOGY**
- 078101 Crystal Growth in Al_{72.9}Ge_{27.1} Alloy Melt under Acoustic Levitation Conditions**
YAN Na, DAI Fu-Ping, WANG Wei-Li, WEI Bing-Bo
- 078102 Fabrication of Hinged Mirrors Using a Strain-Driven Self-Assembly Method on a GaAs Substrate**
ZHOU Yan, WANG Hai-Long, MA Chuan-He, GONG Qian, FENG Song-Lin
- 078103 A Facile Method for Synthesizing TiO₂ Sea-Urchin-Like Structures and Their Applications in Solar Energy Harvesting**
WANG Wen-Hui, WANG Wen-Zhong, XU Hong-Xing
- 078201 Structural Analysis of In_xGa_{1-x}N/GaN MQWs by Different Experimental Methods**
DING Bin-Beng, PAN Feng, FENG Zhe-Chuan, FA Tao, CHENG Feng-Feng, YAO Shu-De
- 078401 Demonstration of a High Open-Circuit Voltage GaN Betavoltaic Microbattery**
CHENG Zai-Jun, SAN Hai-Sheng, CHEN Xu-Yuan, LIU Bo, FENG Zhi-Hong
- 078501 Restabilizing Mechanisms after the Onset of Thermal Instability in Bipolar Transistors**
CHEN Liang, ZHANG Wan-Rong, XIE Hong-Yun, JIN Dong-Yue, DING Chun-Bao, FU Qiang, WANG Ren-Qing, XIAO Ying, ZHAO Xin
- 078502 Numerical Simulation of 4H-SiC Metal Semiconductor Field Transistors**
Kuang-Po HSUEH, Shih-Tzung SU, Jun ZENG
- 078503 Optical Gain Analysis of Graded InGa_N/Ga_N Quantum-Well Lasers**
Seoung-Hwan Park, Yong-Tae Moon, Jeong Sik Lee, Ho Ki Kwon, Joong Seo Park, Doyeol Ahn
- 078504 Significant Improvement of Organic Thin-Film Transistor Mobility Utilizing an Organic Heterojunction Buffer Layer**
PAN Feng, QIAN Xian-Rui, HUANG Li-Zhen, WANG Hai-Bo, YAN Dong-Hang
- 078505 An Analytical Avalanche Multiplication Model for Partially Depleted Silicon-on-Insulator SiGe Heterojunction Bipolar Transistors**
XU Xiao-Bo, ZHANG He-Ming

078901 Constrained Traffic of Particles on Complex Networks

MENG Qing-Kuan, ZHU Jian-Yang

GEOPHYSICS, ASTRONOMY, AND ASTROPHYSICS

079701 Direct Urca Processes with Hyperons in Cooling Neutron Stars

XU Yan, LIU Guang-Zhou, WU Yao-Rui, ZHU Ming-Feng, YU Zi, WANG Hong-Yan, ZHAO En-Guang

ERRATA AND OTHER CORRECTIONS

079901 Erratum: Electrical Properties of Hydrous Forsterite Derived from First-Principles Calculations [Chin. Phys. Lett. 28 (2011) 059101]

WANG Duo-Jun, LIU Zai-Yang, YI Li, SHI Bao-Ping

JUST FOR AUTHORS
— CHINESE PHYSICS LETTERS