POSTERS - Workshop « Photonique & Mesures de précision », 11/10/2016, CNRS

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Poster workshop Photonique & Mesures de précision

Generalized Hyper-Ramsey quantum clocks with composite laser pulses

Auteurs: T. Zanon-Willette[1,2], R. Lefevre[2],

A.V. Taichenachev[3] et V.I. Yudin[3].

1- LERMA, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, F-75005, Paris, France

2 -Sorbonne Universités, UPMC Univ. Paris 06, F-75005, Paris, France

3-Novosibirsk State University, ul. Pirogova 2, Novosibirsk 630090, Russia and Institute of Laser Physics, SB RAS, pr. Akademika Lavrent'eva 13/3, Novosibirsk 630090, Russia

Résumé:

We have formulated the exact analytical expression of a generalized Hyper-Ramsey (GHR) resonance including a clock frequency-shift disturbed by dissipative processes which may limit the coherent interaction time between the laser probe and atoms, molecules or ions.

As a demonstration, a two-dimensional analysis of the clock frequency-shift associated to Hyper-Ramsey spectroscopy versus pulse area and residual uncompensated light-shifts may exhibit some sorts of low sensitive frequency stability regions to decoherence when working at higher pulse areas.

For the next generation of quantum clocks using composite pulses, we present an absolute laser frequency stabilization protocol using a multiple combination of GHR resonances laser phase-steps with atomic population initialization in ground and excited states of a two-level optical transition.

The robustness of the frequency locked point is absolute against pulse area errors and uncompensated probe-induced frequency-shifts in presence of decoherence and relaxation caused by spontaneous emission or collisions.

A ultimate version of a GHR quantum clock will now be able to control probe-induced frequency-shifts in a dissipative environment well below the 10^{-18} level of relative accuracy.

2

Direct optical interfacing of CVD diamond for deported sensing experiments involving nitrogen-vacancy centers

Ludovic Mayer, Thierry Debuisschert, Thales TRT

Nitrogen-vacancy (NV) colour centre in diamond is a very promising tool for sensing applications from magnetometry to thermometry. In this paper, we demonstrate a compact and convenient device for magnetic-field imaging where a commercial single-mode photonic crystal fibre is directly coupled to a commercial high quality diamond sample. The sample is synthesized by means of chemical vapour deposition process and contains a residual nitrogen impurity rate smaller than 1 part per million. We managed to excite and detect efficiently the photoluminescence from an ensemble of NV centres and to perform electron spin resonance experiments where the NV hyperfine structure is perfectly resolved under continuous measurement.

3

Bruit des lasers dans la génération optique d'ondes submillimétriques pour la spectroscopie

François Bondu et Ayman Hallal

Institut de Physique de Rennes, septembre 2016

Le photomélange de deux porteuses optiques sur une photodiode UTC peut fournir une source très accordable. Nous montrons la stabilisation de deux diodes fibrées sur un résonateur optique lui-même fibré, en polarisations orthogonales, avec une électronique dédiée pour contrôler le bruit de fréquence important. Avec les diodes choisies, la source millimétrique/submillimétrique est accordable de 0 à 500 GHz. Nous montrons la densité spectrale des battements de 2 à 92 GHz, correspondant à une excursion de fréquence quadratique moyenne de 100 kHz et une largeur de raie de 30 Hz. Nous montrons par des simulations des mesures peu perturbées par le bruit de phase en spectrométrie moléculaire entre 100 GHz et 1 THz de raies de largeur de 100 kHz, ordre de grandeur de la largeur Doppler de molécules de masse d'une centaine de g/mol lorsqu'elles sont à pression réduite.

4

Métrologie des microfils optiques par diffusion Brillouin

A. Godet[1], A. Ndao[1], K. Phan Huy[1], J.C. Beugnot[1], T. Sylvestre[1], S. Lebrun[2], G. Pauliat[2]

[1] *Institut FEMTO-ST, CNRS UMR 6174, Université Bourgogne Franche-Comté, 25030 Besançon*

[2] *Laboratoire Charles Fabry, CNRS, Institut d'Optique, Université Paris-Sud, 91127 Palaiseau*

Résumé

Nous présentons une technique de mesure tout optique du diamètre de microfils de silice utilisant le processus de rétrodiffusion Brillouin spontanée. Nous montrons que les spectres Brillouin mesurés sur ces microfils font apparaître des résonances caractéristiques de la géométrie du microfil. A l'aide d'un modèle numérique performant, l'excellent accord théorie expérience nous permet de déterminer le diamètre du microfil avec une précision comparable aux mesures FIB et MEB.

1. Introduction

Les diamètres de microfils sont pour la plupart mesurés à l'aide de méthodes difficile à mettre en œuvre (microscopie MEB, FIB), peu versatile (génération d'harmonique [1]), ou pas assez sensible (diffraction [2]). Notre méthode de mesure est basée sur le phénomène de la rétrodiffusion Brillouin, qui permet d'exciter différentes familles d'ondes élastiques (longitudinales, cisaillement et de surface) [3] couvrant un large spectre de résonances allant de 50 MHz à 11 GHz. Chacune de ces résonances vérifie un accord de phase où le vecteur d'onde acoustique correspond à deux fois le vecteur d'onde optique $(K = 2Kp)$. Le diamètre du microfil diminuant, celui-ci voit son indice de réfraction effectif diminuer et, par accord de phase, implique un décalage en fréquence des ondes élastiques. Le spectre Brillouin résultant est alors différent pour chaque diamètre et c'est à partir de cette relation que nous avons développé un modèle numérique pour prédire un spectre Brillouin en fonction de la géométrie du microfil.

2. Caractérisation

Les microfils ont été obtenus à partir d'une fibre standard SMF-28. Celle-ci est attachée à deux platines de translations motorisées qui étirent la fibre en même temps qu'une flamme ramollit sa partie centrale. La forme du microfil est contrôlée par les vitesses de déplacements des deux platines. Après étirage, le microfil reste relié aux sections non étirées de la SMF-28 par des transitions de forme exponentielle ce qui facilite le couplage. Les microfils utilisés possèdent des diamètres allant de 1 μm à 600 nm sur une longueur uniforme de 4 cm et des pertes de transmission totale de 1 dB après étirage. Nous avons réalisé les mesures de spectre de rétrodiffusion Brillouin dans ces microfils à l'aide d'une détection hétérodyne.

Les résultats nous montrent une bonne correspondance entre les spectres Brillouin théoriques et les spectres expérimentaux où les résonances dues aux ondes élastiques de surface et longitudinales se superposent très bien. On peut distinguer grâce au modèle les résonances dues aux transitions et celles dues au microfil. La forme lorentzienne des pics de résonances nous montre aussi une bonne homogénéité des microfils et donc une bonne qualité de fabrication. Les diamètres alors déterminés par les spectres théoriques ont été confirmés par les mesures aux microscopes FIB et MEB avec une différence maximum de 5%. La sensibilité de notre outil peut aller jusqu'à 5 nm sur le diamètre, ce qui correspond à la limite du modèle numérique.

3. Conclusion

Nous avons mis au point une technique très efficace, passive et toute optique de mesure du diamètre et de la qualité d'un microfil. Elle présente une très faible marge d'erreur comparée aux microscopes sur lequel on a pu s'appuyer pour vérifier les diamètres. De plus, c'est une mesure qui peut se faire in-situ après étirage sans aucune manipulation du microfil contrairement à la microscopie FIB ou MEB. Cette technique inédite est un outil adapté pour le design de microfil.

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GPPMM Gas-Phase Photonic & Microwave Materials

GLOphotonics

Giant compression of high energy optical pulses using a commercially available Kagome fiber

M. Maurel[1,2], B. Debord[1,2], A. Dubrouil[3], A. Husakou[1], F. Gérôme[1,2] and F. Benabid*[1,2]
[1]GPPMM group, Xlim Research Institute, CNRS UMR 7252, Université de Limoges, 87060 Limoges, France
[2]GLOphotonics SAS, 123 avenue Albert Thomas 87060 Limoges Cedex, France
[3]Femto Easy, 351 cours de la Libération, 33405 Talence Cedex, France
Keywords: Self-compression, Femto laser, Ultra-short pulse compression

Recent results in laser beam delivery and ultra-short pulse (USP) compression using hypocycloid-core Kagome hollow-core photonic crystal fibers (HC-PCFs) [1] proved that this type of optical fiber is an excellent candidate as a photonic component for these applications. For example, it has been demonstrated that the fiber guided up to 1 mJ of 500 fs wide pulses with no damage, and by a simple combination in the choice of gas and fiber dispersion, the authors achieved both USP guidance with no pulse broadening nor narrowing, guidance with self-phase modulation (SPM) spectral broadening, and finally guidance with over 10-fold self-compression using solitonic dynamics. However, these compression results necessitated both fiber gas-loading-system and bespoke fiber-fabrication, which are not necessarily accessible to the broader research community. Here, we report on a set of results of self-compression of a USP laser based on a commercially available Kagome fiber (PMC-C-YB-7C from GLOphotonics [2]) and with no need of gas loading management. The compression relies on pulse dynamics near the photoionization threshold, which shows a strong and abrupt self-compression via the formation of a soliton at a well-defined pulse energy value and then its break up at higher energy values [3]. By simply adjusting the fiber length from 10 cm to 4 m, we achieved compression of an initial 500 fs from Yb-doped USP-laser down to ~20 fs (a compression ratio >25) over an energy span of 10 µJ- 800 µJ. Figure 1 summarises these self-compression results by showing the typical evolution of pulse width (*lhs*) and FROG (*rhs*) with increasing input energy for a fiber length of 2.5 m. The maximum compression achieved corresponds to a FWHM of 20 fs and occurs at an energy of 70 µJ. The spectral broadening, the soliton red-shift and compression is visible on the FROG [4] evolution with input energy.

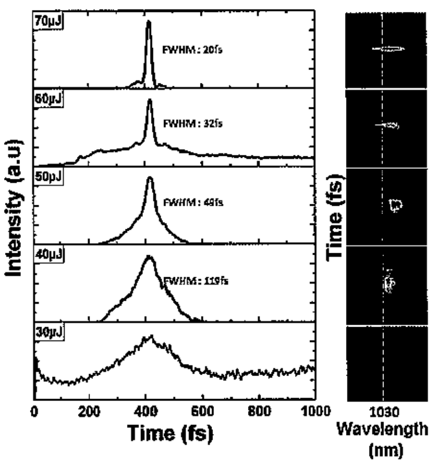

Figure 1. Autocorrelator and FROG traces for different input energy with 2.5 m of Kagome fiber.

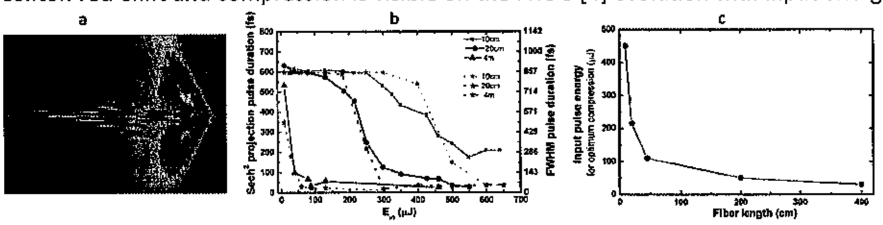

Figure 2. (a) FROG trace of the soliton fission for 2.5 m at 260 µJ. (b) USP compression calculated and measured for different fiber length. (c) Input energy necessary to achieve the maximum of compression at different fiber length.

For higher energy, the pulse breaks up via soliton fission as illustrated in the FROG trace at input energy of 260 µJ [Fig. 2(a)]. Figure 2(b) shows calculated (dotted curves) and measured (solid curves) pulse duration evolution with input energy for different fiber lengths. All curves show a "step shape" corresponding to the sudden compression, and the input energy value at which the self-compression occurs increases with shortening fiber length. Consequently, by simply optimizing the fiber length to the available laser input energy, one achieve optimum compression as shown in Fig. 2(c).

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(6)

DÉMONSTRATION DU PIÉGEAGE COHÉRENT D'ATOMES DE CESIUM AVEC UN VECSEL BIFREQUENCE ET BIPOLARISÉ

P. Dumont[1], S. Janicot[1], F. Tricot[2], D. Holleville[2], S. Guérandel[2], G. Baili[3], L. Morvan[3], D. Dolfi[3], G. Beaudoin[4], I. Sagnes[4], P. Georges[1], G. Lucas-Leclin[1]

[1] *Laboratoire Charles Fabry, Institut d'Optique, CNRS, Univ Paris-Saclay, Palaiseau, France*

[2] *LNE-SYRTE, Observatoire de Paris, CNRS, UPMC, Paris, France*

[3] *Thales Research & Technology, Palaiseau, France*

[4] *Laboratoire de Photonique et de Nanostructures, CNRS UPR20, Marcoussis, France*

RÉSUMÉ

Nous présentons un laser à semiconducteur en cavité externe pompé optiquement accordé sur la transition D2 du césium (852 nm), et émettant simultanément deux fréquences optiques polarisées perpendiculairement. Cette source est destinée aux horloges atomiques à piégeage cohérent (CPT) d'atomes de Cs. La différence de fréquence entre les modes optiques est asservie sur la fréquence délivrée par un oscillateur local à 9,192 GHz. Dans ces conditions, des signaux de résonance CPT bien contrastés sont observés. Les sources de bruit du laser sont évaluées afin de prévoir théoriquement leur impact sur la stabilité d'une horloge, et d'identifier les contributions limitantes.

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(7)

DEVELOPMENT OF A COMPACT FREQUENCY STABILIZED TELECOM LASER DIODE

C. Philippe[1], D. Holleville[1], R. Le Targat[1], P. Wolf[1], T. Leveque[2], R. Le Goff[3], E. Martaud[3] and O. Acef[1]

[1] *LNE-SYRTE, Observatoire de Paris, PSL Research Univ., CNRS, Sorbonne Univ. UPMC Univ. Paris 06,*
[2] *Centre National d'Etudes Spatiales, 18 avenue Edouard Belin, F-31400 Toulouse, France*
[3] *SODERN (Airbus Group), 20 Av. Descartes, F-94451 Limeil-Brévannes, France*

Ouali.acef@obspm.fr

We report on a Telecom laser diode (LD) frequency stabilization to a narrow iodine hyperfine line in the green range, after frequency tripling process using fibered nonlinear waveguide PPLN crystals. We have generated up to 300 mW optical power in the green range (~514 nm) from 800 mW of infrared power (~1542 nm), corresponding to a nonlinear conversion efficiency $\eta = P_{3\omega}/P_{\omega} \sim 36\%$. Less than 10 mW of the generated green power are used for Doppler-free spectroscopy of $^{127}I_2$ molecular iodine, and –therefore- for the frequency stabilization purpose. The frequency tripling optical setup is very compact (< 5 l), fully fibered, and could operate over the full C-band of the C- Telecom band (1530 nm – 1565 nm). Several thousands of hyperfine iodine lines may thus be interrogated in the 510 nm – 521 nm range. We build up an optical bench used at first in free space configuration, in order to test the potential of this new frequency standard based on the couple "1.5 µm laser / iodine". This first setup is based on Doppler free spectroscopy of $^{127}I_2$ hyperfine line, with modulation transfer spectroscopy technique.

We have already demonstrated a preliminary frequency stability of $4.8 \times 10^{-14}\ \tau^{-1/2}$ with a minimum value of 6×10^{-15} reached after 50 s of integration time, conferred to a laser diode operating at 1542.1 nm. We focus now our efforts to expand the frequency stability to a longer integration time in order to meet requirements of many space experiments, such earth gravity missions, inters satellites links or space to ground communications.

Furthermore, we investigate a new approach that aims to reduce significantly the dimensions of the optical bench used to interrogate the molecular iodine vapor. Our target is to develop a fully fibered spectroscopy device. In this case, we use modulation frequency technique associated to 3rd harmonic iodine line detection.

8

WORKSHOP CNRS 11 OCTOBRE 2016

Titre : High power fiber laser for scientific applications

Auteur : G.Guiraud[1, 2], G.Santarelli [1], N.Traynor [2]
[1]Laboratoire Photonique Numérique et Nanosciences, Talence (33)
[2]Azur Light Systems, Pessac (33)

Résumé : Pour répondre aux demandes des applications scientifiques telles que la détection d'onde gravitationnelle ou le refroidissement d'atomes, le développement de sources haute puissance, monofréquence et bas bruit sont indispensables. Nous présentons ici un système tout fibré basé sur des fibres LMA dopées aux ions Ytterbium, émettant 50W continus à 1064nm avec une valeur RMS de bruit d'intensité égale à 0,012% [1kHz/10MHz]. Ce laser, via différents étages de doublage en fréquence, permet d'obtenir des sources visibles et ultraviolettes de forte puissance et de faible bruit.

9

Noise investigation of DFB lasers for compact atomic clocks: time-dependent linewidth and sensitivity to optical feedback

Authors
Nicolas von Bandel[a,b], Mikhaël Myara[b], Michel Krakowski[a], Philippe Signoret[b]
[a] Thales-Nokia III-V Lab, Palaiseau
[b] Institut d'Electronique et des Systèmes, Université de Montpellier, Montpellier

Presentation
Poster preferred (in english)

Abstract
In the frame of the LAMA project (Laser diode Modules for High performances Atomic clocks), laser diodes addressing the Cesium D1 line (894nm) have been developed to comply with the requirements of the industrial Optical Cesium Frequency Standard (OFCS). Among others, the linewidth of these lasers should be less than 1 MHz at Full-Width Half-Maximum to limit the impact of laser frequency noise on the setup. Also, they should be relatively resistant to optical feedback, which can perturb the operation of the clock on the long term. Thus, special attention has to be devoted to the noise characterization of these devices. Traditionally, the linewidth is measured by an Electrical Spectrum Analyzer using a beat note, be it in an heterodyne or self-heterodyne configurations. However, in the case of non-white noise components in the spectral profile of lasers (diode lasers, external cavity lasers...), theses techniques are not satisfying, as they do not take properly into account the time-dependency of the linewidth with time. Here, we show that the full noise characteristics (both linewidth and frequency noise) can be recovered using a single high-quality digital sampling and signal processing of the heterodyne beat note. In addition, we investigate laser noise profile of modules under external feedback. Indeed, it has been noticed that such external perturbations can be detrimental to the electronic stabilization of the laser on the Cesium lines.

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Compact Raman gaz self-organizing into deep nano-trap lattice

M.Chafer[1,2], M. Alharbi[1], A.Husakou[1], B. Debord[1,2], F. Gérôme[1,2] and F. Benabid*[1,2]
[1]GPPMM group, Xlim Research Institute, CNRS UMR 7252, Université de Limoges, 87060 Limoges, France
[2]GLOphotonics SAS, 123 avenue Albert Thomas 87060 Limoges Cedex, France

Keywords: Stimulated Raman Scattering, Hollow-core fiber, Optical lattice, Molecular trapping

This project is to generate a high power and narrow linewidth continuous wave (CW) Raman laser based on a Hollow-Core Photonic Crystal Fibers (HC-PCF) filled in with hydrogen at high pressure for frequency conversion via Stimulated Raman Scattering (SRS). Such a laser will permit to fulfill one of the requirements for the long term objective to develop an optical waveform synthesizer akin to an electronic one. Beyond the possibility of generating a high power narrow linewidth Raman laser, the linewidth is found 6 orders of magnitude lower than the expected Raman pressure broadened linewidth with a spectrum witnessing a Lamb-Dicke regime with sub-Doppler spectral-width emission. This counter-intuitive result stems from an original dynamics whereby molecules self-organize to be trapped into nano-meter wide and ultra-deep potential array [1][2]. Here we report on theoretical and experimental analysis of such original dynamics. The experimental set-up comprises a narrow linewidth (400kHz), high power (100W) CW laser working at 1061 nm coupled in a Photonic Band Gap (PBG) HC-PCF filled with hydrogen at high pressure (5-50bar), a core radius of 3.2μm and a loss of 70dB/km. Thanks to its transmission window (1-1.2μm) we can filter any other Raman conversion but the targeted resonance, namely the Raman rotational transition $S_{00}(1)$ ($\upsilon_{S00(1)}$ =17.2THz). We can see in Fig. 1a numerical results of the evolution of pump, Forward Stokes (FS), Backward Stokes (BS), and the Raman gain coefficient (g_r) power versus the fiber length typical of a SRS process, *i.e.* a gradual depletion of the pump and a quick rise of the FS and BS in the Raman generation length. The zoom in the gain region (Fig. 1b) shows that the normalized population difference between the two levels of the Raman transition D (black curve), the g_r (red curve) and the medium energy potential (blue curve) are spatially modulated with a period of half the Stokes wavelength. They alternate between nanometers wide Raman active regions where the SRS occurs and a saturated Raman region. The active regions create 3D trapping wells for the hydrogen molecules with depths of 55THz and 200MHz in the longitudinal and the transversal direction. This self-assembled nanostructured optical lattice corroborates with the Lamb Dicke regime and sub-Doppler structure seen experimentally (see Fig. 1c). The linewidth measured using the self-heterodyne technique is as low as 3kHz, instead of the 2GHz Raman pressure broadened linewidth, with sidebands at 200kHz. These sidebands are associated with the transversal motion of the molecules inside the traps. Fig. 1d shows the linewidth over a larger span exhibiting additional sidebands at 8MHz, which is the signature of the Rabi frequency splitting set by the mixing of the pump field with that of the Stokes, in good agreement with the 10MHz calculated. The sidebands at 16 and 24MHz are caused by Four Wave Mixing (FWM) between the lower-order sidebands. The sidebands at 10-17GHz (Fig. 1e), measured via diffracting the FS, are the longitudinal motional sidebands which is in the range of the 3-17GHz calculated. We can also observe an asymmetry in the amplitude of the red shifted sideband and the blue one indicating a thermal distribution in quantized harmonic oscillator. Finally, in changing the fiber length and the gas pressure we can tailor the power and the linewidth of the Raman laser. For a 7m long fiber at 20bar we can generate a high power Raman laser up to 58W for FS, with a linewidth smaller than 200kHz. For a 30m long fiber filled at 5bar we can get a linewidth of 3kHz.

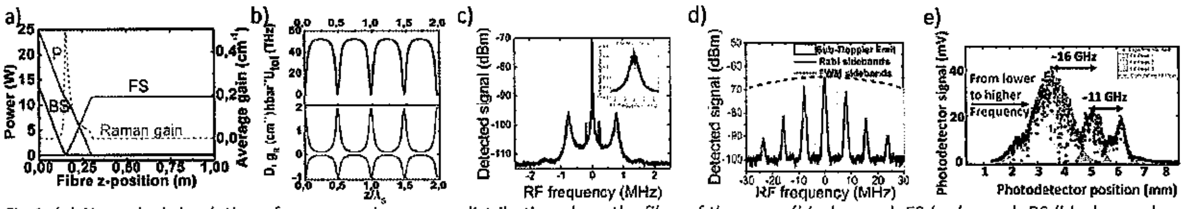

Fig.1: (a) Numerical simulation of macroscopic power z-distribution along the fiber of the pump (black curve), FS (red curve), BS (black curve) and g_r (grey curve); (b) Microscopic z-distribution of g_r (red curve), population difference (black curve) and potential (blue curve); (c) 4MHz span and 20kHz span for P_{in}=11W and P=5bar; (d) 60 MHz span of FS P_{in}=11W and P=5bar; (e) Photodetector signal versus its position for P_{in}=20W and P=15bar

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11

Mesure de la vitesse de recul d'un atome en combinant l'interférométrie atomique avec la technique des oscillations de Bloch

C. Courvoisier, M. Andia, R. Jannin, F. Nez, F. Biraben, P. Cladé et S. Guellati-Khélifa*

Laboratoire Kastler Brossel, UPMC, CNRS, ENS, Collège de France
4, place Jussieu, F-75005 Paris, France
*+Conservatoire National des Arts et Métiers; 292 rue St-Martin 75141 Paris, France

La technique des oscillations de Bloch dans un réseau optique accéléré permet de transférer aux atomes un nombre élevé de reculs avec une grande efficacité (99,97% par recul). Dans notre expérience nous combinons cette technique avec un interféromètre atomique Ramsey-Bordé pour mesurer précisément le rapport *h/m* entre la constante de Planck *h* et la masse d'un atome de rubidium *m*. Cette mesure nous a permis de déterminer la constante de structure fine α avec une précision inégalée à ce jour. Nous avons également utilisé cette technique pour démontrer un schéma compact de gravimètre atomique avec une sensibilité très prometteuse.

Dans ce poster, nous présenterons les développements récents réalisés sur cette expérience.

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assembly of optical systems in free-space

Ludovic Fulop
KYLIA
www.kylia.com
ludovic.fulop@kylia.com

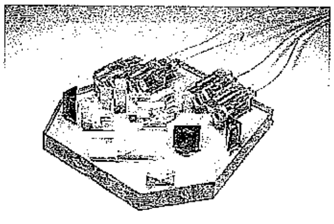
kYLia

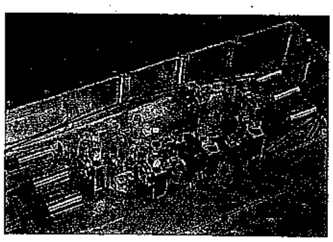
Kylia's expertise is **ultra-precise assembly** of optical elements to buid **optical systems in free-space** :

- Ultra-precise assembly (up to 10 nm and 10 µrad) of optical elements (lenses, prisms, beam splitters, polarizers, collimators...) on glass or metal breadboards, using 6D positioning.
- Integration of external technologies : photodiodes, laser diodes, liquid crystal cells, MOEMS, magneto-optical cells...
- Athermal conception by :
  - using low CTE material (fused silica, ZERODUR or ULE, invar, SiC...)
  - design and material choices to compensate the thermal behaviour of « high CTE » components
- Stable and robust devices, made to be used in extreme environment (Kylia's assembly technology is Telcordia qualified).

KYLIA Paris
10, rue de Montmorency
75003 Paris

KYLIA Pessac
11, avenue de Canteranne
Cité de la Photonique
Batiment Elnath
33600 Pessac





(13)

Stabilisation et réduction de la largeur de raie d'un laser accordable autour de 1,55 µm avec une cavité en anneau fibrée et référencée

Pierre Gruning[1], Amine Chaouche-Ramdane[1], Min Lee[1], Vincent Roncin[1],

Frédéric Du-Burck[1], Stéphane Trebaol[2], Pascal Besnard[2]

[1] *Laboratoire de Physique des Lasers UMR CNRS 7538, Université Paris 13 – Sorbonne Paris Cité, 93430 Villetaneuse, France*

[2] *CNRS FOTON UMR 6082, ENSSAT, Université de Rennes 1,6 rue de Kerampont, 22300 Lannion, France*

RÉSUMÉ

Nous présentons un dispositif permettant de stabiliser la fréquence d'un laser accordable et de réduire sa largeur de raie spectrale. Il repose sur une cavité en anneau fibrée de configuration originale, stabilisée sur une référence métrologique. Le laser est une diode laser à cavité étendue accordable sur 100 nm autour de 1,55 µm. Le dispositif peut alors être utilisé comme outil de stabilisation, de référencement ou de filtrage optique. Nous présentons les premiers résultats en termes de stabilité et de filtrage.

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(14)

MiTICC :
Miniature Trapped Ion Clock on a Chip

Maël Souidi, Jacques Millo, Rodolphe Boudot, Emmanuel Bigler, Vincent Giordano, Yann Kersalé, Clément Lacroûte, FEMTO-ST

contact: mael.souidi@edu.univ-fcomte.fr

The purpose of this work is to design and realize an optical atomic clock based on the 435,5nm quadrupole transition of the $171Yb^{+}$. The study aims at obtaining a frequency stability of 10-14 at one second of integration time in a complete setup volume of less than 500 liter.

To achieve this performance, the Ytterbium ions will be created directly in the device from the crossing of an Ytterbium atom beam and an ionization laser source.Then, the ion will be laser-cooled and trapped by electrodynamic fields to limit the energy of the ion and constrain its movement. In order to satisfy the volume constraints we will design a microfabricated surface-electrode (SE) trap and a reduced vacuum chamber for the charged particles. We will also use fibered optical components whenever possible.

SE traps are usually used in quantum information processing setups. The use of such a device in a metrological experiment should also allow the fine characterization of the trap characteristics, such as heating rates and coherence times.

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Time Transfer over a White Rabbit network

Namneet Kaur, Paul-Eric Pottie, Philip Tuckey

SYRTE, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, LNE, 61 avenue de l'Observatoire, 75014 Paris, France.

Email: namneet.kaur@obspm.fr

Time transfer through optical fiber links has gained significant recognition in the past few years, following the impressive developments in the area of frequency transfer over the last decade. Today, a very promising direction for time transfer is the implementation of White Rabbit PTP (Precision Time Protocol) technology [1] on wide area networks. White Rabbit is a novel technology developed at CERN, based on PTP using Synchronous Ethernet and other techniques to achieve high performance. It demonstrates sub-nanosecond time stability and synchronization of arrays of instruments over 10-km scale networks. The challenges are the extension to longer distances [2] and the development of absolute time calibration [3].

In view of time dissemination on active telecommunication networks, we are exploring uni-directional configurations for White Rabbit links [2]. Our objective is the development of a scalable and compatible network time transfer approach providing multiple user dissemination, competitive with GNSS-based time distribution. Our first trial uses White Rabbit for short range time dissemination inside Paris Observatory's campus, on a mid-range fiber link. Our experimental schematic is shown in Fig 1. We will present experimental characterizations of phase noise, Allan deviation and time stability of commercially existing White Rabbit solutions, for uni- and bi-directional topologies, and our progress towards precise time transfer.

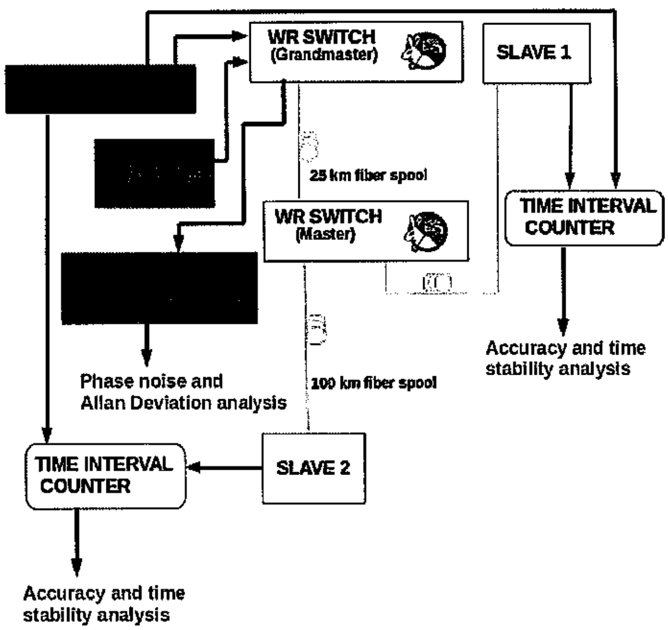

Figure 1. Experimental setup.

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Sensitivity to variations of the fundamental constants from frequency splittings between acetylene reference lines at 1.5 μm

Florin Lucian Constantin[1]

[1]Laboratoire PhLAM, UMR CNRS 8523, 59655 Villeneuve d'Ascq, France

KEYWORDS : variation of the proton-to-electron mass ratio; rovibrational Hamiltonian; rovibrational spectroscopy; acetylene frequency standard.

A possible temporal variation of the fundamental constants, addressed in modern theories (for a review see for example [1]), can be detected in molecular physics by precision measurements. Molecular spectra are intrinsically sensitive to $\mu=m_e/m_p$. The approaches to probe a variation of μ were the frequency measurements of molecular clocks based, for example, on ammonia inversion transitions detected in a fountain [2], respectively rovibrational transitions of trapped molecular hydrogen ions [3] or diatomic molecules in optical traps [4] and on a two-photon transition in a molecular beam [5] that pushed the constraint of a variation of μ at 5.6×10^{-14} yr^{-1}. This contribution proposes to exploit highly sensitive frequency splittings between near-resonant transitions of the acetylene grid [6].

The experimental setups developed in many laboratories (see for example [7]) are based on an extended cavity laser diode with external electro-optic modulation that is locked with the Pound-Drever-Hall method to a Fabry-Perot cavity filled with acetylene. The metrological performances are a short term (<1 s) laser linewidth of ~50 kHz, an Allan fractional stability of $\sim10^{-12}$ at 1 s and a reproducibility of ~1 kHz on a day-to-day timescale. Acetylene transitions have been measured with an accuracy of ~1 kHz using frequency comb techniques. The proposed approach is to count the optical beat at a microwave frequency X between two similar systems locked to adjacent acetylene lines against the Cs clock frequency f_{Cs}. Small linear time variations of the fundamental constants lead to a small linear time variation of the frequency ratio X/f_{Cs}. As the Cs clock frequency dependence is $f_{Cs}\sim g_{Cs}\alpha^{2.83}\mu$, the contribution of the fractional time variation of μ to the temporal drift of X/f_{Cs} is amplified by the sensitivity coefficient $d(\ln X)/d(\ln\mu)$.

The energy levels of the ground state, respectively of the combination vibrational states are modelised with a Hamiltonian [8] that accounts for rotation, centrifugal distortion, vibration, anharmonicity and different rovibrational interactions. The sensitivity of the rovibrational transitions of the v_1+v_3, respectively the $v_1+v_2+v_4+v_5$ bands are calculated. Near resonant transitions arise from the cancellation of the rotational intervals with frequency shifts associated to the isotopic effect, the origins of the vibrational bands, the anharmonicity or the rovibrational interactions. The frequency splittings have sensitivity coefficients up to $\pm10^3$ level. The systematic frequency shifts of the frequency splittings may be lower than those of one transition. The systematic effects are conservatively estimated at 96 Hz for actual experimental setups and the constraint to a fractional variation of μ is derived at 10^{-10} level.

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(17)

Phase lock and laser characterization for dark resonance spectroscopy of rf trapped ions

M. Collombon, R. Khayatzadeh, G. Hagel, M. Houssin, D. Guyomarc'h, O. Morizot, C. Champenois, and M. Knoop

PIIM, UMR7345, Aix-Marseille Université, CNRS, Marseille, France

Coherent population trapping allows to exploit multi-photon spectroscopy with a very high precision [1]. A cloud of trapped ions is an excellent sample to measure, for example, transition dipoles with an uncertainty inferior to 10^{-3}, necessary to push forward today's best calculations [2].

Our ion of choice is Ca+, which is laser-cooled by two lasers at 397 nm and 866 nm, while the excitation of its electric quadrupole (clock) transition is made at 729 nm. We have developed and realized a narrow linewidth laser at this latter wavelength that attains a relative frequency stability below 5.10^{-14} per second for periods inferior to 10 seconds. This optical wave at 729 nm is transported by a 150m long phase-noise cancelled fibre to the experimental setup.

In order to phase-lock all involved laser sources, we make use of an offset-free commercial frequency comb [3]. In the final experimental configuration, the frequency comb is locked to the 729 nm-laser, while the 866nm and 794 nm (=2*397 nm) lasers are phase-locked to the frequency comb.

We have characterized all phase noise contributions, in order to evaluate the ultimate frequency stability we can attain. As the frequency comb is a novel equipment, a particular effort has been made to characterize its performances with respect to our stable laser and GPS. Measurements are ongoing and results will be reported.

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Thermal and Cold Atom optics in hollow-core PCF: Towards cold atom Photonic MicroCell

Ximeng Zheng, GPPMM group, Research Institute XLIM, UMR7252 CNRS &University of Limoges, 123, Avenue Albert Thomas, 87070 Limoges

The long-term aim of this research activities is to develop cold-atom Photonic MicroCell (CA-PMC). A CA-PMC is stand-alone hollow-core photonic crystal fibre (HC-PCF) filled atomic vapour (e.g. Rb, Cs...) sealed with low-loss splice to solid optical fibers. The atoms are then laser cooled with a judicious modal laser excitations. Towards this aim, the GPPMM research group is undertaking the following works: (1) the design and fabrication of tailored HC-PCF, (2) HC-PCF post processing for inner-core coating, tapering, gas loading for PMC assembly; (3) Atom spectroscopy and (4) laser cooling and Cold atom handling in HC-PCF.

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Liens optiques ultrastables pour les futurs réseaux métrologiques

Olivier Lopez et al., *Laboratoire de Physique des Lasers UMR CNRS 7538, Université Paris 13 – Sorbonne Paris Cité, 93430 Villetaneuse, France*

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Stabilisation en fréquence de sources lasers auto-impulsionnels à semi-conducteur

Amine Chaouche Ramdane et al., *Laboratoire de Physique des Lasers UMR CNRS 7538, Université Paris 13 – Sorbonne Paris Cité, 93430 Villetaneuse, France*

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Conference on Precision Electromagnetic Measurement, CPEM2018 à Paris

François Piquemal - LNE

L'édition 2018 de la conférence CPEM, « *Conference on Precision Electromagnetic Measurements* » aura lieu à Paris, Maison de la Chimie, du 8 au 13 juillet 2018. C'est la plus importante manifestation scientifique et technologique dans le domaine des mesures électromagnétiques de très haute précision.

Organisée par le Laboratoire national de métrologie et d'essais (LNE) en collaboration avec l'Observatoire de Paris et le Centre national de la recherche scientifique (CNRS), la conférence couvrira le spectre de fréquences qui s'étend du continu jusqu'aux fréquences optiques et concernera des applications liées aux mesures électriques (courant, tension, impédance, puissance, champ électrique...), mesures du temps et des fréquences, mesures optiques et radiométriques.

2018 sera une année charnière dans l'histoire du Système international d'unités (SI), puisqu'elle doit être l'année de l'adoption de nouvelles définitions pour le kilogramme, l'ampère, le kelvin et la mole. Toutes les unités de base du SI seront alors définies à partir de constantes de la physique. CPEM 2018 offrira donc l'occasion idéale pour marquer cette étape particulièrement importante en se concentrant naturellement sur les dispositifs quantiques qui relient les étalons de mesures électriques aux constantes fondamentales de la physique.

CPEM 2018 sera aussi le lieu d'échange de connaissances sur les recherches en métrologie menées dans des domaines relatifs à l'électromagnétisme pour relever les défis actuels et futurs adressés à l'industrie et la société dans les applications telles que l'énergie, les technologies de l'information et de la communication (nanomatériaux, les objets connectés...), l'ingénierie quantique, l'Industrie 4.0, etc.

Plus de 400 participants en provenance de plus de 40 pays à travers le monde sont attendus pour CPEM 2018. CPEM attire de nombreux experts qui travaillent au sein d'instituts nationaux de métrologie ou de laboratoires publics (universités, centres de recherche) spécialisés dans les mesures de précision, des métrologues du secteur industriel ou appartenant à des agences gouvernementales et des représentants de fabricants d'instruments de mesure et de références de haute précision.

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Un peigne de fréquences ultra-stable et accordable pour la spectroscopie moyen-IR à très haute résolution

Dang Bao An TRAN et al., *Laboratoire de Physique des Lasers UMR CNRS 7538, Université Paris 13 – Sorbonne Paris Cité, 93430 Villetaneuse, France*

(23)

Inhibited Coupling Hollow-Core Photonic Crystal Fibers

New guidance mechanism for myriad of gas-laser applications

B. Debord[1,2], M. Maurel[1,2], M. Chafer[1,2], F. Gérôme[1,2] and F. Benabid[1,2*]
[1] GPPMM group, Xlim Research Institute, CNRS UMR 7252, Université de Limoges, 87060 Limoges, France.
[2] GLOphotonics S.A.S, 1 avenue d'Ester, Ester Technopôle, Limoges, France.

We review a new guidance concept of hollow-core photonic crystal fiber (HC-PCF), coined inhibited-coupling (IC) mechanism where the guidance is achieved no longer by absence of cladding modes (e.g. photonic bandgap or total internal reflection) but by suppressing the coupling between the core guided mode and the cladding mode continuum. This new approach led to the development and fabrication of highly performant HC-PCFs that are basis of a myriad of gas-laser applications, heart of GPPMM group activities (Non linear and coherent optics, Plasma photonics, Molecular and atom optics).
Two kind of IC HC-PCF are presented, differentiated by their cladding structure. The first one is based on a Kagomé lattice which demonstrated propagation loss as low as 8.5 dB/km around 1 μm and 70 dB/km in the visible spectral range. The other design, developed more recently, relies on a tubular lattice fulfilling completely the guiding rules of IC mechanism in which the surface scattering loss has been reduced resulting in. record loss at shorter wavelength (7.7 dB/km at 750 nm) and guidance demonstration for the first time down to 220 nm.

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(24)

Sonder un mode polaritonique de surface avec l'interaction Casimir-Polder

Joao Carlos DE AQUINO CARVALHO et al., *Laboratoire de Physique des Lasers UMR CNRS 7538, Université Paris 13 – Sorbonne Paris Cité, 93430 Villetaneuse, France*

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(25)

Beam self-action in planar chalcogenide waveguides

Tintu KURIAKOSE **et al.**, *FEMTO-ST, 15B Avenue des Montboucons, 25030 Besançon, France*