Two-wavelength Laser Interferometry with a Single Two-wavelength Lasers

Jean-Pierre Wallerand, Thomas Bhadr, Marc Himbert and Marin Nenchev Nenchev

Abstract - **During the development of system for two-wavelength laser interferometry (in our case - for high precise measurement of long distances), we have investigated and observed experimentally that the non-exact superposition of the two beams that formed the "synthetic wavelengths" is not critical for the system action, if these beams is parallel and closely each to other. We investigate experimentally this effect that shows the primary importance of the superposition of the two wavelengths in the recovers. This observation develop the potential to simplify essential the system, using at the place of two lasers a single two-wavelength laser that produce the two emissions in closely osculate parallel beams. The essential advantage is that for such laser the no "wavelength competition effect" occurs and the two emissions is independently controlled without influence each to other and respectively very stable. We propose our proper, very simple, solution of such lasers**

Keywords – **two-wavelength interfereometry, simultaneous two-wavelength laser operation**

I. INTRODUCTION

The two-wavelength laser interferometry [1] , based on the use for measurement of distances in Michelson type schemes (MI) so-called "synthetic wavelength", the last formed by interaction of spectrally closed (~ 10^{-5} nm) two laser light (λ_1 and λ_2) is continuously actual[2]. This "synthetic wavelength" is given by $\lambda_s = \lambda_1 \lambda_2 / |\lambda_1-\lambda_2|$ and is essentially longer (~ few or tens centimeters) that $\lambda_1$and λ_2 and thus, it is possible to measured very small phase changes in this " synthetic wavelength" when the length of some of the MI arms is changed. Consequently, this permits to measured a change of distance of tens and more meters with precision of part of millimeters. Note that is the part of the developed project, using as one of variants the discussed about technique, to measured length of kilometer with precision of part of millimeter. [3].

Here, on the base of observation in our experiment, we present some practical property of such system – the correct action with closely disposed parallel laser beams and the approach to simplify the system, using a single two-wavelength laser.

A. Discussion of the problem, experimental observation and proposal of a simple solution

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Actually, in practice, in all described in the literature realization of "synthetic wavelength" systems, the desire is to use two exactly superimposed beams of the light, obtained using two separate lasers [1-2]. This need, except the two expensive laser sources also précis optical arrangement for exact superimposing theirs beams. The natural idea to use a single, two-wavelength laser that produces emission in the two wavelengths in a single beam is given in the literature [4, 5] with development of such type of lasers. The two wavelength laser with emission in a single beam are well developed in the literature [6- 7], however, its use is related with essential drawback – the strong "wave competition" that is accompanied with a strong competition between the two simultaneous generation and respectively with essential fluctuation of theirs spectral and energetic parameters [6].

In experimental two-wavelength laser interferometer scheme, realized in INM/BNM CNAM [3] (of the type, given in Ref. [1]), it was used two frequency doubled cw Nd:YAG lasers .The main investigations was by using the precisely superposition of the two green (doubled 1.06 um light with frequency difference of 300 MHz, obtained using acousto -optical modulation of the beams). The operation of the system in the preliminary experiments with of few tens meters of difference in the Michelson Interferometer arms was perfect, and reproduced very well the reported results in Ref.1.

During our experimental work on the development of this system for operation of essentially long distances [3], we have investigated the effect of non-exact superposition of the two beams. It was found by us a very similar action of the system by using two closed or exactly parallel beams at the place of completely superimposed beams. We obtain such spatially close each to other and completely parallel beams by the translation of one of the beams using a thick (1 cm) plane parallel glass plate GPL before the superposition of the beams in the basic scheme. By small rotation of the plate we can spatially translated in parallel manner one of the beams and realized from completely superposition to the beams to completely spatial separation, preserving their parallelism. Schematically, the arrangement is given in Fig.1. In Fig.2 is shown the glass palate. In Fig.3 are given the spot of the parallel beams in the cross-section for tree rotation of the glass plate. In Fig.4 are given the oscilloscope traces of the "synthetic wavelength" (top-reference from photo detector RE_1 and bottom -this one after superposition of both beams, passing the arms of the interferometer –from ER_2. The left oscillograms are for completely superimposed beams (Fig.3a), the right –for parallel (Fig.3c). Only a small decreasing of the amplitude is observed.

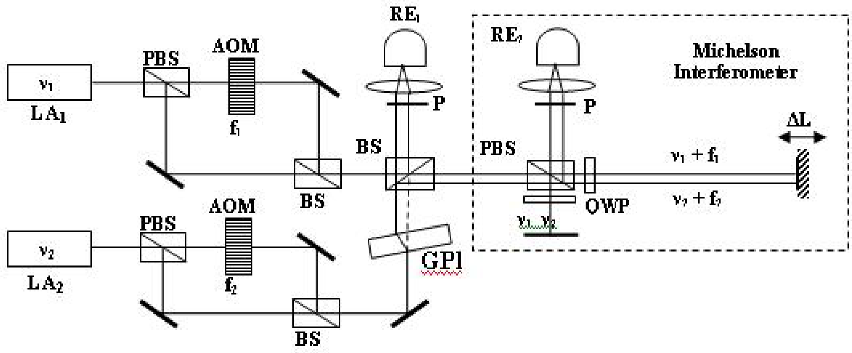

Fig. 1 .Schematically presentation of the arrangement, used for two wavelength laser interferometry (measurement of change of the length of one arm of the Michelson Interfetometer). LA_1 ,LA_2 - two frequency doubled (0.53 um), single mode, cw Nd:YAG lasers, PBS's-polarizing beam splitters, AOM,s-acousto-optic modulators, OWP-quarter-wave plate,M_1,M_2, deaf mirrors, RE_1 and RE_2 , the high-sped optical receivers with focused lens in the input, GPL – glass palate, P -polarizer

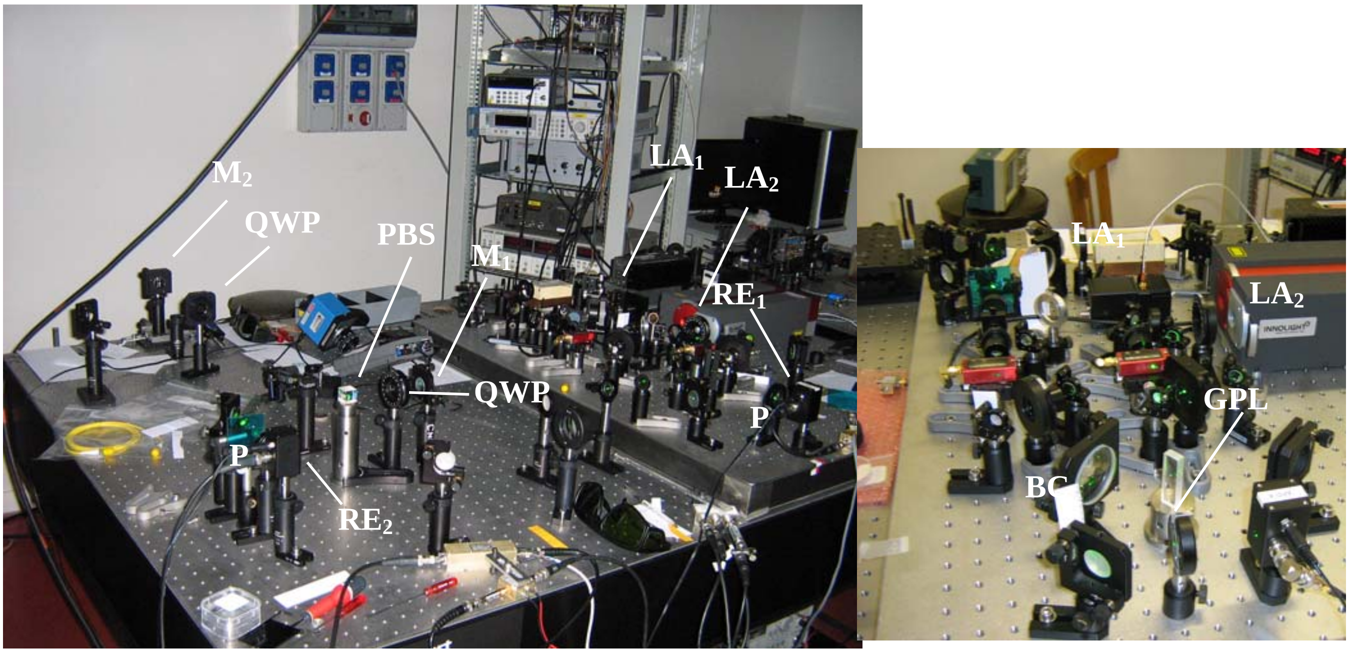

Fig. 2 an actual photograph of the realization and in the incept – the part of the system with a glass separated plate GPL. The notations are as in Fig.1.

a) b) c)

Fig. 3. The spot of the parallel beams in the cross-section for tree rotation of the glass plate.

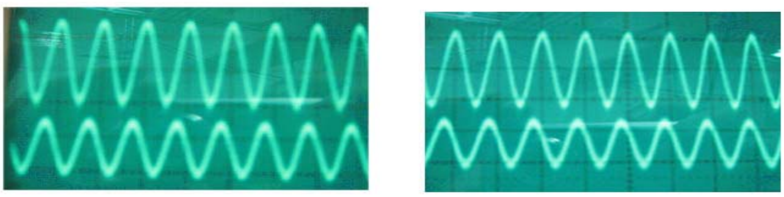

Fig. 4 The oscilloscope traces of the "sinetic wavelength" (top-reference from photo-detector RE_1 and bottom -this one after superposition of both beams, passing the arm of the IM –from ER_2., (the full scale 2.5 GHz)

This observation is very important of point of view of use of single, two-wavelength laser as a laser source in the system and respectively –the simplifying of the system. In the literature are developed the lasers that easily produce a two generation with an independent control of each wavelength and without any competition between both generations. Here, on the bas of the discussed our observation, on the base of our earlier proposal [7], we propose a simple, reliable and very convenient two-wavelength laser of discussed type.

B. The two-wavelength lasers with generation in parallel beams with independent control of each generation and without generation's competition

Earlier, we have proposed a few solutions when a single laser, using only one active medium, produces two emissions with independent temporal and spectral control [6]. Here we develop further our previous proposal in new simplest scheme for producing from one active medium two independently controlled emissions in spectrum (at wavelength λ_1 and λ_2) and emitted in closely disposed and exactly parallel beams. We considered also the more actual case of diode pumping of the laser. As we have discussed before, such lasers are of essential interest for simplifying the two-wavelength interferometry systems. Here, due to the desired only very low spectral distance (~ few hundred MHz) between two lights, it is easy to obtain such operation as a single mode emission from two different parts of a single pumped volume of one active medium. In Fig. 5 and Fig.6 are shown schematically our solutions of such diode pumped lasers. The firs scheme permits completely independent tuning of the wavelength in each beam in large range (from few MHz to GHz in the band of amplification). The second scheme is simplest, but the tuning is limited only in the selected range, essentially low (~ few hundred MHz) that the tuning in the first scheme. However, for the special proposal of two-wavelength laser interferometry it is very convenient.

The action of the proposed lasers can be understood from the applied figures 5 and 6. In the figures the active medium is Nd:YAG crystal with dimensions 1.5x1.5x1.5 mm, especially produced for diode laser pumping. The crystal is cooled by the Peltie system (not shown in the Figures) to constant room temperature of 22 ^{o}C. It was closely disposed to the dichroic mirror $M_{3,}$- transparent (~89%) for the focussed by the lens L_3=7 cm) pump radiation of wavelength of 0.81 um and deaf for 1.06 um. The lens L_4 with antireflection coated surfaces for 1.06 um and focal length of 5 cm is focused on the mirror M_3 and collimated the Nd:YAG laser emission as it s shown in Fig.5 and 6.

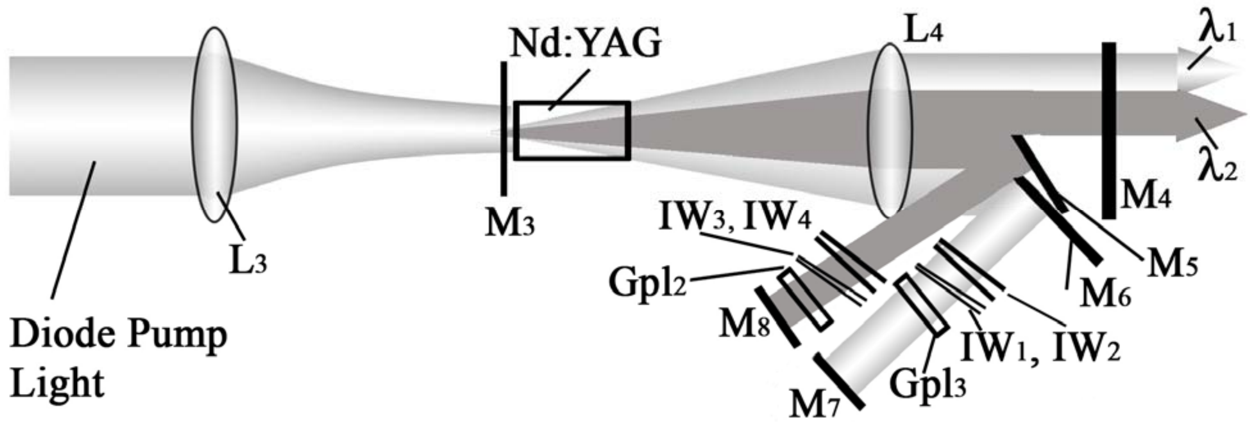

Fig.5 .Two-wavelength laser with independent tuning of the two wavelength and the two selected modes

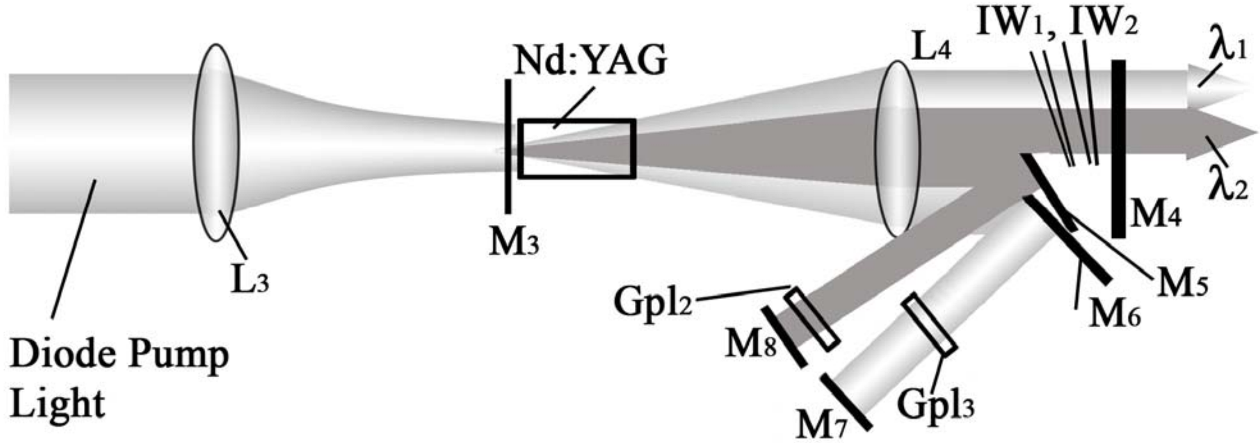

Fig.6.Simplified scheme of a two-wavelength laser with independent tuning of the two selected modes

By returning this emission, using the 92 % reflectivity end mirror M_4 the laser start to generated in large beam of ~ 2.5 cm By introducing the intracavity separating deaf mirrors M_5 and M_6 we forms in one part of the intracavity parallel beams two channels with different direction of propagation. We close each channel with deaf mirror (M_7 and M_8 respectively). Thus we obtain two cannels. Each of them permits independent temporal and spectral control. The emissions from both channels are in exactly parallel propagation and closely disposed each to other. In the scheme in Fig.5, by introducing two appropriate interference wedges as it is described in our previous work [6] we can separate a single mode emission at each channel. By slowly rotation of one of the flat glass palate, we can adjusted the frequency position of each mode and obtain the needed difference between the two wavelength. Also, in this scheme, by translation of the IW_1 and (or) IW_2 we can tune the wavelength in each channel. In the scheme in Fig.6 we can adjusted in the necessary spectral place the wavelength of both generations, but the tuning of this wavelength is related. The important possibility is that by the glass plate GPl2 and GPl_3 we can tuned independently the selected mode frequency, what permits to adjusted it's a necessary frequency distance for the interferometric system operation.

The preliminary test of the proposed laser, not included actually, in the interferometric system, shows its feasibility and work as it is described.(experiments with the laser in Fig.6). The diode pumping by 10 W power leads to ~ 2 W sum laser output in both channel. The spectral analysis shows stable single mode operation in both channels and controlled frequency distance between the two modes. Thus, the developed two wavelength laser show the potential for real application in the two-wavelength interferometric system with possibility to simplified and make chipper tthis system. Due to very closely spectral disposition (~ hundred MHz difference) of the two modes in the channels, the condition of its generation are practically completely equal and a little correction by the GPL2 and GPL_3 can assure its simultaneous generation.

II. Conclusion

In the work we have shown experimentally that the two-wavelength interferometic system of the Michelson type can operate not only using a completely superimposed beams, but also can operate very well using closely disposed and parallel beams. This permits to make the system essentially chipper and simpler by using a single two-wavelength lasers that produces the two wavelengths in different parts of the single active medium, without mode competition effects (the last make the laser operation very stable end reliable). We have also given two simple solutions of such diode pumped Nd:YAG lasers.

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