



Investigation of the Absorption Lines of a Kr - Ne - Mixture as Wavelength Standards for Optical Communication Systems in the Range of 1270 nm - 1640 nm

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Short Research Article

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ABSTRACT

Optical communication systems are since the last 25 years the backbone of all international data and telecom communications. Up to now, more than 10 TBit/s can be distributed via one optical fiber in long-haul systems. This was realized by the use of highly parallel multi-channel transmission via many colors, called Wavelength division multiplex (WDM). Here, the International Telecommunication Union specified the channel location into a frequency space grid with 100GHz distance in the infrared regime from 1300nm to 1640nm. To avoid interference between these densely arranged transmission channels, each transmitter output frequency has to be stabilized exactly in its center frequency to others. To supervise and stabilize the transmission comb, absolute frequency standards are very helpful to be integrated into optical cross-connect stations. Using excited state absorption lines of a Nobel gas is an easy way to generate reference frequencies, because these states are very stable and very small in linewidth. A well known method is the detection of the absorption by the opto-galvanic effect (OGE). Here, a tube is filled with an gas like Kr and the detection of the absorption will be performed by an electrical signal of the absorption cell via electrodes with high voltage supply. Many atomic transitions are near by to the ITU grid frequencies of ITU G 652 Recommendation. In this article we show for our knowledge at the first time all absorption lines of krypton

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and neon mixed gas in the whole ITU transmission range between 1270nm -1640nm using optogalvanic spectroscopy. The temperature dependence of the possible wavelength drift of the detected lines was also measured using a climate chamber between 10°C and 50°C. The measured absorption lines are within the tolerances of the detection equipment in comparison to literature. The measured stronger lines are separated between 5 nm and 30 nm in the detected wavelength range. Hence the creation of a frequency grid using 27 pure stable absorption lines of Kr as a wavelength standard for optical communications systems using these lines would be possible. Combining the Galvatron detection of Kr lines with active feedback to a multi-channel laser source, a high stable reference source for optical WDM networks would be available in future.

Keywords: WDM; optical references; optical networks; opto galvanic spectroscopy.

1. INTRODUCTION

Atomic and molecular absorption lines are used in a wide range of optics as a wavelength calibration references, since these form even under fluctuating ambient conditions highly stable frequency standards. Molecules such as acetylene and hydrogen cyanide have very narrow-band absorptions in the range of 1500 nm [1,2,3,4]. These transitions can be easily detected directly by absorption spectroscopy. Atomic transitions of rare gases in the range of 1300-1700 nm are generally not directly detectable because they are transitions between excited states of the atom. Usually, these excited states are produced by means of laser excitation or by an electrical gas discharge. A single gas laser reference line from the HeNe laser at 1523 nm is available. More atomic or molecular references can only frequency doubling of light from eg Rubidium of 1560 nm was achieved at 780 nm, which is only feasible with very high equipment costs [5].

Internationally with the cesium standard [6] is a source with an accuracy of 1.5×10^{-14} available. Based on this, imagine a class of reference laser in optical communications technology area to be established. These portable laboratory standards [7] with a frequency accuracy of 10^{-9} (0.2 MHz at 200 THz, 1500 nm) to represent an important link between the non-portable reference laser and the less accurate field equipment. Should the distance between two reference frequencies of 20 nm does not exceed to score sufficiently small distance between two calibrations to allow a spectrometer. These laboratory standards make a very demanding electronics and beam guidance necessary to avoid the Doppler broadening of the natural line width of the absorptions used [8,9,10].

2. EXPERIMENTAL SETUP

Fig. 1 shows the test site with the equipment used. From the tunable laser source (4) the laser beam is modulated by the chopper wheel (7) intensity. The control unit of the chopper (3) is connected to a phase sensitive lock-in amplifier (2) which detects the change in electrical voltage in the Galvatron tube (6), voltage supply (1)), since the signal by the discharge current very is noisy. With the wavemeter (5) the wavelength is determined with an accuracy of 3×10^{-13} at the same time. In the Galvatron-tube, the isotopes of krypton are included in the following proportions (Table 1). It also contains as a filling gas Neon, the cathode is made of iron.

Table 1. Isotopic proportions of natural krypton gas [10]

Isotope	⁷⁸ Kr	⁸⁰ Kr	⁸² Kr	⁸³ Kr	⁸⁴ Kr	⁸⁶ Kr
Part [%]	0,35	2,28	11,59	11,49	57,00	17,30

In examining the temperature dependency the Galvatron tube was placed in a climate chamber.

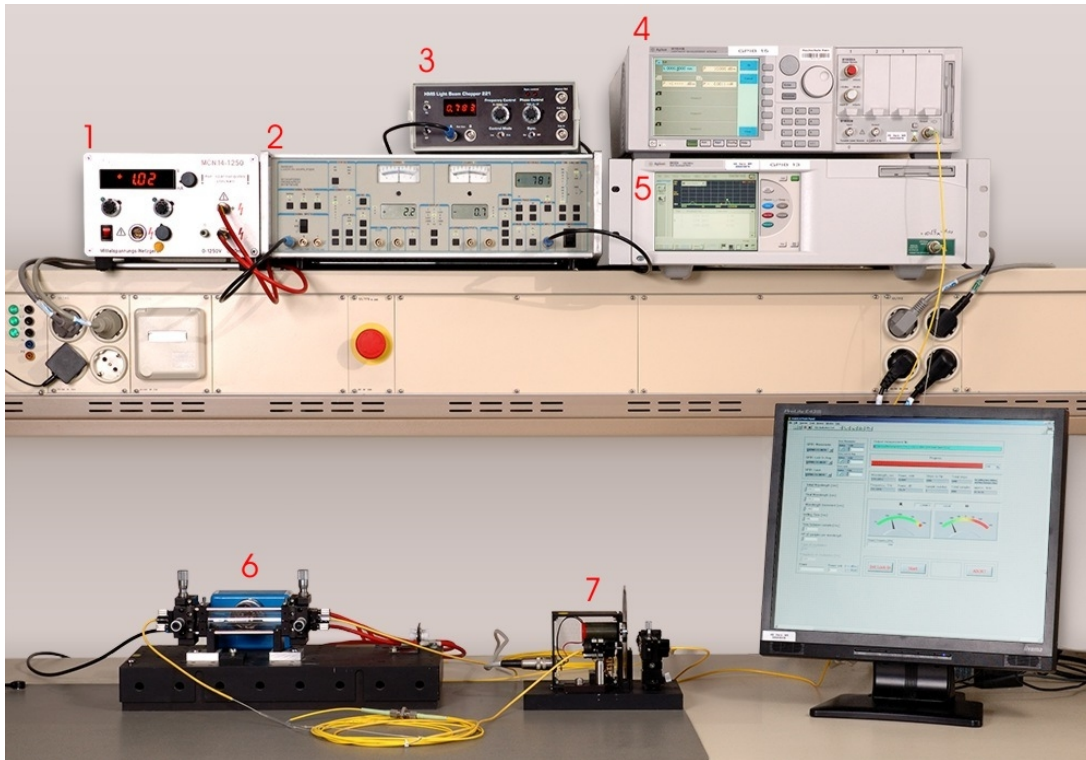


Fig. 1. Experimental setup 1: High voltage source, 2: lock-in amplifier, 3: chopper controller, 4: Agilent tunable laser source, 5: Agilent high resolution wavemeter, 6: Galvatron tube with optical coupling setup, 7:chopper wheel

Fig. 2 shows the schematic setup of and the connections between the devices used. All units were controlled with the help of the GPIB interface of a LabVIEW program that increases the wavelength of the laser source from a start value to an end value with a fixed step size. The intensity of the lock-in amplifier and the wavelength is read at the wavemeter and stored in a file. Since the wavelength range could not be covered by a laser source, 3 different sources with the following areas a) were 1270-1375 nm b) 1370-1480 nm, and c) used from 1440 to 1640 nm.

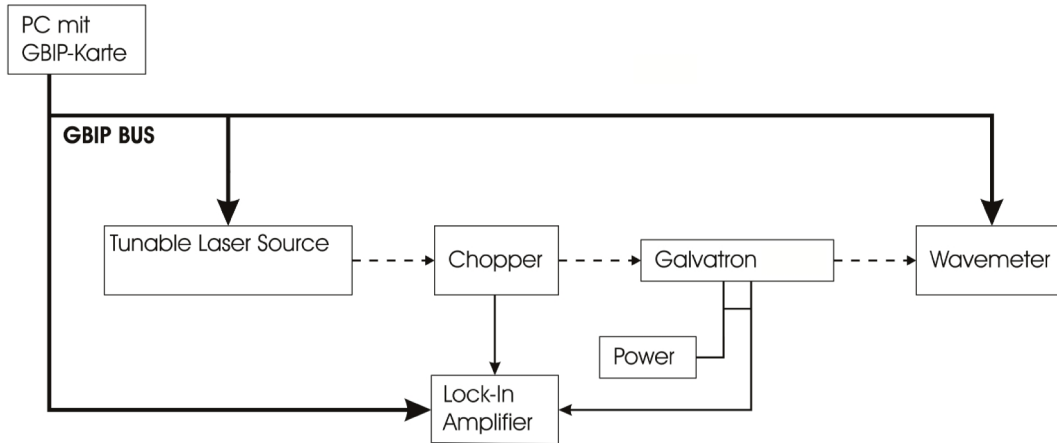


Fig. 2. Schematic electrical and optical connections of experimental setup

In Fig. 3, the measure section is depicted beginning at the laser source via the chopper, the Galvatron-tube to the wavemeter. In the experiments, the laser source is operated with an output power of 10 dBm, which is lowered by the loss of connectors and especially by the chopper and the Galvatron-tube down to -21 dBm at the wavemeter.

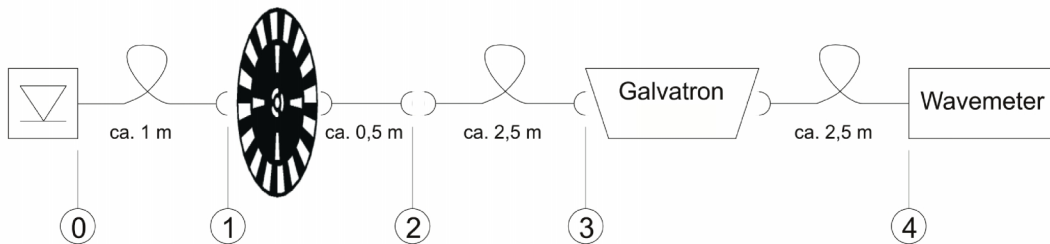


Fig. 3. Optical path of setup: 0: tunable laser source, 1: optical chopper wheel, 2: opt. connector, 3: Galvatron tube, 4: optical high resolution wavemeter

3. RESULTS AND DISCUSSION

First, the absorption lines of krypton and neon in the range of 1270-1640 nm were measured. To our knowledge this is the first continuous measurement and presentation of this interesting for optical communication systems wavelength range. In Fig. 4, there are the consistently numbered absorption lines of Galvatron tube in the areas of laser sources.

It should be noted, is that lines of neon (eg line 01), iron (eg line 27) and carbon (eg line 15) were measured. These were using the database of the NIST determined [11]. Afterwards, at selected lines ({1286.54123 nm line 03}, {1374.26111 nm line 10} and {1547.82593 nm line 41}) the influence of temperature on the drift of the intensity maximum is investigated. As an example the results of the krypton absorption line shown at 1286.54 nm (Fig. 4d) is depicted. The picture shows the superposition of three isotopes of krypton and the Gaussian fit of the three individual lines. The resulting deviations of the wavelengths from those described in the literature [12,13] are due to the measurement accuracy of the wavemeter.

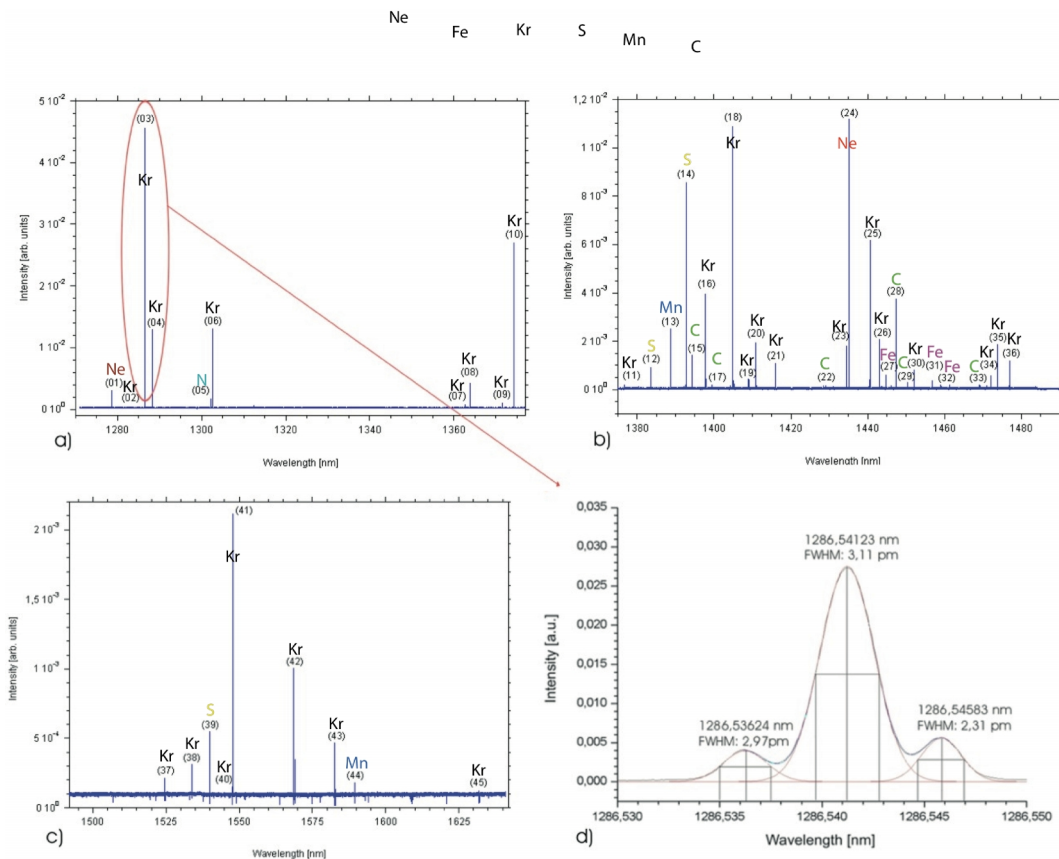


Fig. 4. Summary of the absorption lines and display of Kr line 1286.54123 nm at 10°C, a) Kr-absorption lines between 1200nm – 1380nm, b) Kr-absorption lines between 1380nm – 1490nm, c) Kr-absorption lines between 1490nm – 1640nm, d) high resolution absorption spectrum Kr 1286nm-line

In the tests no drift of the main peak as a function of temperature could be determined (see Table 2). The half-maximum-value width of the main peak remains almost constant. In the secondary maxima a slight broadening was observed with increasing temperature.

Tab. 2. Values of the lines at 1286.54106 nm at various temperatures

T[°C]	λ_1 [nm]	FWHM ₁	λ_2 [nm]	FWHM ₂	λ_3 [nm]	FWHM ₃
10	1286,53624	2,52	1286,54123	3,11	1286,54583	2,31
20	1286,53619	2,56	1286,54121	3,24	1286,54584	2,33
30	1286,53621	2,58	1286,54120	3,11	1286,54581	2,34
40	1286,53621	2,63	1286,54121	3,12	1286,54582	2,34
50	1286,53623	2,73	1286,54122	3,12	1286,54583	2,45

4. CONCLUSION

First time, all absorption lines of krypton and neon mixed gas in the range of 1270-1640 nm were measured and displayed. The measured absorption lines show little deviations on the dates given in the literature. The largest deviations were ± 0.5 pm, which can be explained already by the measurement accuracy of the wavemeter.

The stronger lines are separated between 5 nm and 30 nm. Hence the creation of a frequency grid as a wavelength standard for optical communications systems would be possible. Since the absorption lines do not depend on the temperature, the use of a krypton-filled tube Galvatron appears useful as a frequency reference for optical networks.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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