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Multiwave laser source for simultaneous sounding ozone and critically related to ozone chemicals

S.M.Baschenko

Institute of Physics of NAS of Ukraine, 46, prospect Nauki, Kiev, Ukraine, 03039

Abstract. The scheme of multiwave laser source, suitable for simultaneous probing ozone and chemicals critically related to ozone (such as HCl, $ClONO_2$, N_2O_5, HNO_3) participating in its formation and destruction, when using differential absorption with scattering method (DIAS) for sounding, is suggested.

Such a source may consist of excimer laser complex complemented with a converter implementing Stimulated Raman Scattering phenomena. Both complex and converter are assembled and operate using "oscillator-amplifier" optical scheme, which provides simultaneous generation at few wavelengths in a wide spectral range due to discrete Raman conversion with its fine tuning due to complex implementation.

Experimental pattern of 3-waves laser source elaborated with this scheme is described. In our attempt laser source consists of XeCl*-excimer laser complex supplemented with SRS-converter with dense hydrogen. Possibilities of simultaneous generation at three lines - 308, 353 nm and one of the wide set: 414, 499, 635 or 855 nm – with fine tuning of all lines within up to 1 nm are demonstrated.

The advantages of offered scheme and difficulties in its realization are discussed.

Keywords: excimer laser, SRS-conversion, ozone sounding, critically related to ozone chemicals, DIAS Lidar.

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1. Introduction

Evidence that human activities affect the ozone layer has been building up over the last 20 years, ever since scientists first suggested that the release of chlorofluorocarbons (CFCs) into the atmosphere could reduce the amount of ozone in upper layers.

The breakdown products (chlorine compounds) of these gases were detected in the stratosphere. When the ozone hole was detected, it was soon associated with a concentration increase of these chlorine compounds. The loss of ozone was not restricted to the Antarctic, approximately at the same time the first obtained evidence was produced that there had been an ozone decrease over the heavily populated northern mid-latitudes (30-60N). However, unlike the sudden and near total loss of ozone over Antarctica at certain altitudes, the loss of ozone in mid-latitudes is much less and much slower – only a few percentage per year. However, it is a very worrying trend and the one, which ought to be the subject of intense scientific research at present.

Many of these findings have been reinforced by a variety of internationally supported scientific investigations involving satellites, aircraft, balloons and ground stations, and the implications are still being quantified and assessed.

In trying to understand how these ozone losses occurs and the role of critical issues destroying so much ozone, it would be necessary to look at and better to measure these critical issues simultaneously with ozone concentration.

To realize these, it is desirable that radiation source (beside power, repetition rate and other features) would be able to provide possibilities to:

- generate the most suitable for ozone sounding wavelengths, i.e. - 308 and 353 nm;
- choose a complementary line/lines from sufficient set in wide spectral region and generate it simultaneously with the first two;
- change operatively these complementary lines;
- tune finely at least this complementary line or all of these.

In our opinion such a promising radiation source may be designed on a base of power laser added a proper converter: laser provides (beside other parameters) fine tuning of generated lines. Proper converter provides a wide set of lines possible to generate in sizable spectral region, where required critical to ozone chemicals have significant absorption.

As a radiation source, we propose to use two excimer lasers, which are joined into the complex by "master oscillator – power amplifier" scheme that provides:

- light pulse energy sufficient enough for sounding over any reasonable distance;
- radiation divergence close to diffraction limit;
- spectral width of radiation less then part of cm^{-1};
- fine tuning the line generated within part of excimer molecule luminescence band;
- a possibility to utilize part of pulse energy for conversion into other spectral lines of radiation.

As converters, the solid-state, liquid and gaseous ones may be successfully used. We propose to use SRS-converter that is assembled by "master oscillator – power amplifier" scheme and provides possibility of high-efficient conversion into the definite (higher) SRS-component from the widest set of lines over spectra. In the case of XeCl*-laser and hydrogen or methane SRS-converter these sets are as follows: 203, 222, 245, 273, 353nm, 414, 499, 631, 855nm and 213, 227, 243, 261, 283, 338, 375, 421, 480, 559, 668 nm and so on, respectively.

2. Experimental part

The experimental 3-waves laser source was patterned by offered scheme. As main, basic element of the source, the excimer XeCl*-laser complex is used. It consists of two synchronized XeCl*-lasers with optical scheme "master oscillator – power amplifier" (MOPA) and assembled on a common optical table. It is necessary to note that for effective joining these two lasers just in the complex, their special development was carried out. The essence of it consists in vertical configuration of a laser head contrary to the standard horizontal one, and purpose does in achievement of a laser head minimal width. As a result of this development, it became possible to group the laser block in width only 240 mm (!). It is this arrangement that allowed to place all optical elements of the "oscillator – amplifier" scheme on a common, established on a few invar cores, optical plate of width only 600 mm and, using it, to achieve effective optical joining of lasers in the united complex with high stability of radiation parameters. Such an effective optical joining cannot be achieved with a simple association of two lasers with a typical width 800 mm — you see in this case an optical plate would have a width more than 1600 mm with all the following consequences: vibrations, weight, etc.

Due to this, radiation of the complex has the excellent energetic (20–30 mJ), spatial (high directivity is equivalent to low divergence $Q \sim 10^{-4...5}$ radians), temporary ($t \approx 25$ nanosecond) and spectral characteristics ($\Delta\lambda \leq 0{,}1$ см$^{-1}$). It has power enough for sounding over any reasonable distances.

In its turn, these characteristics of radiation allows both fine tuning within one nanometer range (bandwidth of generation spectra) and SRS-conversion possibility in Raman-active gases – hydrogen, methane. It must be marked, that there is important possibility of SRS-conversion into the higher Stokes and anti-Stokes components by "oscillator – amplifier" scheme. Preliminary experiments have demonstrated quantum efficiency of similar SRS-conversion up to 50-60%.

3-waves laser irradiator has the next characteristics:

- main line of generation – 308 nm;
- SRS-conversion in dense H_2 provides 353 nm (first Stokes component) and additional line with wavelength 414 or 499 nm;
- fine tuning (simultaneously at all three lines) over a range slightly less than 1 nm;
- energies of radiation pulses is 1-5 mJ;
- pulse duration is 25 ns;
- repetition rate up to 50 pps.

We consider that such a scheme of multiwave laser source construction has a few advantages, namely:

- it is able to generate a few lines simultaneously;
- it is able to provide both the discrete transforming in wide region of spectra and fine tuning over 1 nm range;
- it is possible to provide any relationship among lines' intensities in the case of SRS-conversion by "oscillator-amplifier" scheme;
- there is a possibility of conversion over a wide region of spectra, which is necessary to match sounding wavelength to main absorption wavelengths of required chemicals;
- in comparison with solid-state and liquid transformers gaseous media have a many times higher threshold of damage and cannot be made inoperative in the case of threshold exceeding;
- gaseous converter has more wide spectral range, it is less selective and does not require spectral matching with pumpung light source, which distinguish it from the solid-state or liquid ones.

The experimental source pattern was elaborated for implementation in the constitution of DIAS Lidar being under design for Atmosphere Monitoring Laboratory at the Institute of Physics, NASU.

With this Lidar implementation we expect to conduct simultaneous measurements of ozone and critically related to ozone chemicals in the atmosphere over the region of the Laboratory. We hope that these measurements will help to understand ozone forming, destroying as well as transporting channels and mechanisms.

Conclusions

Preliminary testing 3-wave experimental pattern have demonstrated both its attractive simplicity, reliability,

For further information:
Tel: 380 (044) 265 1482, Fax: 380 (044) 265 1543, *E-mail: baschenk@iop.kiev.ua

efficiency and suitability for simultaneous remote sounding of ozone and critically related to ozone chemicals.

References

1. Measures R.M., *Laser Remote Sensing*, John Willey & Sons, Inc. 1984
2. Hinckley E.D., *Laser Monitoring of the Atmosphere*, Springer-Verlag. 1976
3. Zuev V.E. et al., *Remote optical Sensing of Atmosphere*, Gidrometeoizdat, Moscow, 1992.
4. Zuev V.E. et al., Lidar for Sounding of Tropospheric Ozone Using a Copper-vapor Laser and Excimer Laser, *Proc. 17th Int. Laser Radar Conf.,* Sendai, Japan.
5. Vassy E., Ann. de Phys., (11) **8**, 679 (1937).