The electron beam cleaning is one of a new perspective
gas smoke cleaning methods. Electron beams with power 0.1-
3 MW are used in a such method. Radiation beams are produced
by the electron beam in a gas medium and it can extract such
gas admixtures: NO\textsubscript{x} - up to 90%, SO\textsubscript{x} - up to 95%.

Sources of gas ion intensity beams are also widely used in
national industry for generation, for example: N\textsuperscript{2+}, SF\textsubscript{6}, He\textsuperscript{+} [1].

A waveguide CO\textsubscript{2}-lasers (CO\textsubscript{2}-WL) with the exit intensity modu-
lation are used for plasma diagnostics precision systems.

The pump current modulation method has some advantages
among a various modulation methods [2]. It is used because of an
effective collision frequencies of electrons and ions with other
plasma components are: 10\textsuperscript{11} (electrons) and 10\textsuperscript{9} (ions) s\textsuperscript{-1},
what is sufficiently higher then the modulation frequency for our
plasma parameter characteristic (constant current, whole gas
mixture pressure CO\textsubscript{2}:N\textsubscript{2}:He p=20 kPa, current density i=200 mA/sm\textsuperscript{2},
gas temperature T=300 K). These values show, that electron concen-
tration change follows after the discharge current change without
delay practically for discharge current modulation frequency, if it
is less 1 MHz. The dynamical range knowledge of modulation frequency
is needed for this method. The dependence of intensity exit modu-
aluation depth (Y axis) is nonlinear in respect to frequency
(X-axis), on the plane. At first, it is decreasing slowly from
maximum value which is equal to 1, with the frequency growth. Then,
it reaches bend-point on the 0.7 maximum level and begins decrease
quickly to 0.3-0.2 of maximum level. Then, the speed decreasing is
more slow with respect to frequency growth and the dependence
approaches to the X-axis assimptotically.

The mathematical model was elaborated for the intensity exit
modulation analysis. A basic processes of a molecule vibrational
levels were taken into account for CO\textsubscript{2}, N\textsubscript{2} and for CO, which is
formed in the discharge.

The analytical expression was obtained for the intensity exit
of modulation depth CO\textsubscript{2}-WL with gas mixture CO\textsubscript{2}:N\textsubscript{2}:He [3]:

HEDRICK IHT RAS, Moscow, Russia
\[ m_I = \left[ a_{23} - (\gamma_1 + j\omega) + W(g_3 - g_2) \right] \left[ \Gamma_4 \Gamma_9 - \Gamma_6 \Gamma_7 \right] - R_{12} N_1 \left[ \Gamma_9 (\Gamma_5 + \omega g_2) - \Gamma_6 \Gamma_7 \right] / \left[ \left( (\gamma_1 + j\omega) + \omega g_2 \right) (\Gamma_5 \Gamma_9 - \Gamma_6 \Gamma_8) + \omega g_2 \Gamma_1 \Gamma_9 \right], \]

Here, indexes 1, 2, 3 are related to basic, lower and upper CO₂ laser levels, respectively; 4, 5 - to upper and lower CO level; 6, 7 - to upper and lower N₂ level, respectively; \( a_{ln} \) - an excitation transmission velocity from level 1 to the level n; \( \gamma_{ln} \) - an excitation relaxation velocity from level 1 to the level n; \( R_{ln} \) - is a pumping velocity of n level from 1 level; \( \Gamma_1 = a_{23} + \delta_{\omega g_3} \), \( \Gamma_4 = R_{13} N_1 + a_{64} R_{76} N_7 / \gamma_6 \), \( \Gamma_5 = a_{63} a_{36} / \gamma_6 - (\gamma_3' + j\omega + \omega \delta_{\omega g_3}) \), \( \Gamma_6 = a_{43} + a_{46} a_{63} / \gamma_6 \), \( \Gamma_7 = R_{54} N_5 + a_{64} R_{76} N_7 / \gamma_6 \), \( \Gamma_8 = a_{34} + a_{64} a_{36} / \gamma_6 \), \( \Gamma_9 = a_{64} a_{46} / \gamma_6 - \gamma_4 \), \( \gamma_3' = \gamma_3 + j\omega \), \( \gamma_4 = \gamma_4 + j\omega \),

\[ \gamma_6 = \gamma_6 + j\omega, \quad \gamma_3' = \gamma_3 + a_{34} + a_{36} + a_{32} + \beta_3, \quad \gamma_4' = \gamma_4 + a_{46} + \beta_4 \]

\[ \gamma_6' = \gamma_6 + a_{63} + a_{64} + \beta_6 \]

\( g_2, g_3 \) - statistical weight of lower and upper CO₂ molecule laser levels; \( \delta \) - stimulated emission cross section on 0001-1000 transition; \( W \) - is a photon beam power density in a laser resonator; \( Y = \Sigma \delta_i \), \( \delta_i \) - mirror losses; \( \delta_2 \) - losses from waveguide mode fixing with free space mode; \( \delta_3 \) - channel waveguide losses; \( \delta_4 \) - gas dispersion losses; \( \beta_1 = b_1 D_1 \Lambda^{-2} \) - excitation relaxation by 1 level on a channel waveguide wall; \( D_1 \) - diffusion ambipolar coefficient; \( b_1 \) - numerical coefficient, which depends on waveguide wall material and gas mixture; \( \Lambda \) - is a diffusion length.

CO molecule concentration \( n_{CO} = f/(1-f) \), here \( f \) is CO₂ dissociation degree under the active medium pumping definite conditions.

A values \( m_I (\omega) \) were calculated for various gas mixtures in 2.5 - 22 kPa pressure range. Experimental investigations of CO₂-WL modulation characteristics were made in a BeO discharge tube: length - 180 mm, inner diameter - 2 mm. Experiments show, that
a dependences $m_\text{I}(\omega)$ are nonlinear.

A $\text{CO}_2$-WL optical resonator contains two flat internal mirrors, which are arranged near discharge tube ends. A temperature of discharge tube external wall was equal to $16^\circ \text{C}$. A generator-modulator was connected with the pump electric circuit through $C_1$ dividing capacitor, without preamplifier [3]. Experimental data ($\circ$, $\Delta$) and calculated curves (solid line) are shown at Fig.1.

Calculated curves and the experimental results have good agreement almost up to 0.1 of maximum. The agreement is less accurate for values less 0.1 of maximum, because of signal/noise increase. After an experimental measurements of the intensity modulation depth $m_\text{I}(\omega)$ one can define $\text{CO}_2$-WL modulation frequency range $\Delta\nu = \nu_h - \nu_1$ ($\nu_h$, $\nu_1$ - upper and lower boundary frequency, $\nu = \omega/2\pi$). $\nu_h$ is the frequency, on which the relaxation processes influence inside active laser medium, it corresponds to 0.7 of maximum level on the curve. The experimental value $\nu_d$ is in the 100-200 Hz range. A $\Delta\nu$ values are 2.1 and 5.4 kHz, for example, in a gas laser medium $\text{CO}_2$ : $\text{N}_2$ : $\text{He}$ = 1:1:7 with $p$ = 6.7 and 13.2 kPa, respectively. The 1-10 kHz modulation frequency experimental range is quite enough for row various diagnostic applications.

A $\text{CO}_2$-WL are a great interest, because, it has a small weight, dimensions and energy consumption. The $\text{CO}_2$-WL can be used in a various complex diagnostics. A small gas neutral molecule concentrations as the background level can be discovered with the help of such laser [4]. A different gas molecule can be produced in a gas medium by plasma and ion intensity beams. Such a diagnostic is based on the gas molecule absorption spectral line center coincidence with a gas laser radiation line frequency, which can
be switch over by hand or by automatic. Obtained results were 
suprising for the next gas neutral molecule concentrations: \( \text{O}_3 \), 
\( \text{H}_2\text{O} \), \( \text{CO}_2 \), \( \text{C}_2\text{H}_4 \), \( \text{NH}_3 \) in a optical airway investigations. A \( \text{CO}_2\text{-WL} \) 
are used for noxious gas admixtures diagnostics, so as \( \text{NO}_x \) and 
\( \text{SO}_x \) in a various processes ecological monitoring.

A \( \text{CO}_2\text{-WL} \) are used for different ion beam concentration 
measurements and also, for example, \( \text{SF}_6 \).

A waveguide \( \text{CO}_2 \)-laser with frequency reformation is elaborating now. The laser is supplied with frequency stabilization system 
and with maximum of contour amplification automatic tuning. The wa-
velength reformation range is 9-11 \( \mu \), it corresponds to the line 
branch 9R, 9P, 10R, 10P; laser power is 3 W in the centre of lines 
and 0.2 W is on the edge of lines; by 19-20 lines are in the 
each branch. A photoreceiver with Ge:Au up to 77 K cooling cristal 
or pirolelectrical semiconductor structure can be used for useful 
signal register.

For a neutrals concentration definition of lidar signal measure-
ments various methods are used: spline-function method, Tihonov 
regularization method and optimal parametrization method [5].

Many investigators preferences to the spline-function method. 
An exaction of spline-function depends on a smoothing 
parameter value. The discrepancy criterion was applied for the 
search of parameter. An information of middle mistakes are needed 
for the whole measurement range in such a criterion [6].

A more effective \( \text{CO}_2\text{-WL} \) wavelength were defined for atmos-
phere gas mixture analysis: \( \text{H}_2\text{O} - 10P(40) [1,9 \times 10^4] \), \( \text{O}_3 - 9P(14) 
[0,03] \), \( \text{NH}_3 - 9R(30) [5 \times 10^{-4}] \), \( \text{C}_2\text{H}_4 - 10P(14) [0,02] \), here, 
an ordinal numbers of \( \text{CO}_2\text{-laser} \) P, R - branch radiation lines 
point out in a parentheses, minimum observable atmosphere gas 
concentration ( ppm ) point out in a square brackets.

A single-wave method is used for near ground atmosphere gas 
mixture analysis. The error systematic contribution in a dis-
persion is proportional to a background level in a such a method. 
However, the gas concentration observable minimum in the 
single-wave method is equal to the gas concentrations observable 
minimum in a differential method by small systematic mistake 
\( \xi_{sys} = 0.01 \) [7]. The single-wave method can be used for such 
quantity analysis, therefore.
Such IR lasers can found applications in a complect of board devices for various measurements in a near earthly space, also.

References