Applications of excilamps in environmentally appropriate technologies

E-mail: badik@loi.hcei.tsc.ru
High Current Electronics Institute SB RAS,
Tomsk, 634055, ave. Akademicheskii 2/3

Edward. A. Sosnin

Key words: excimer and exciplex lamp (excilamps), photochemistry, photobiology, photomedicine, foodstuff quality control.

Plan of presentation

Current report reviews recent experimental results concerning the use of modern excilamps (excimer and exciplex lamps) in environmentally appropriate technologies (EAT).

Part 1. Excilamps – What is it?
Part 2. Excilamp Applications
Part 3. The offers on cooperation in creation of environmentally appropriate technologies based on excilamps

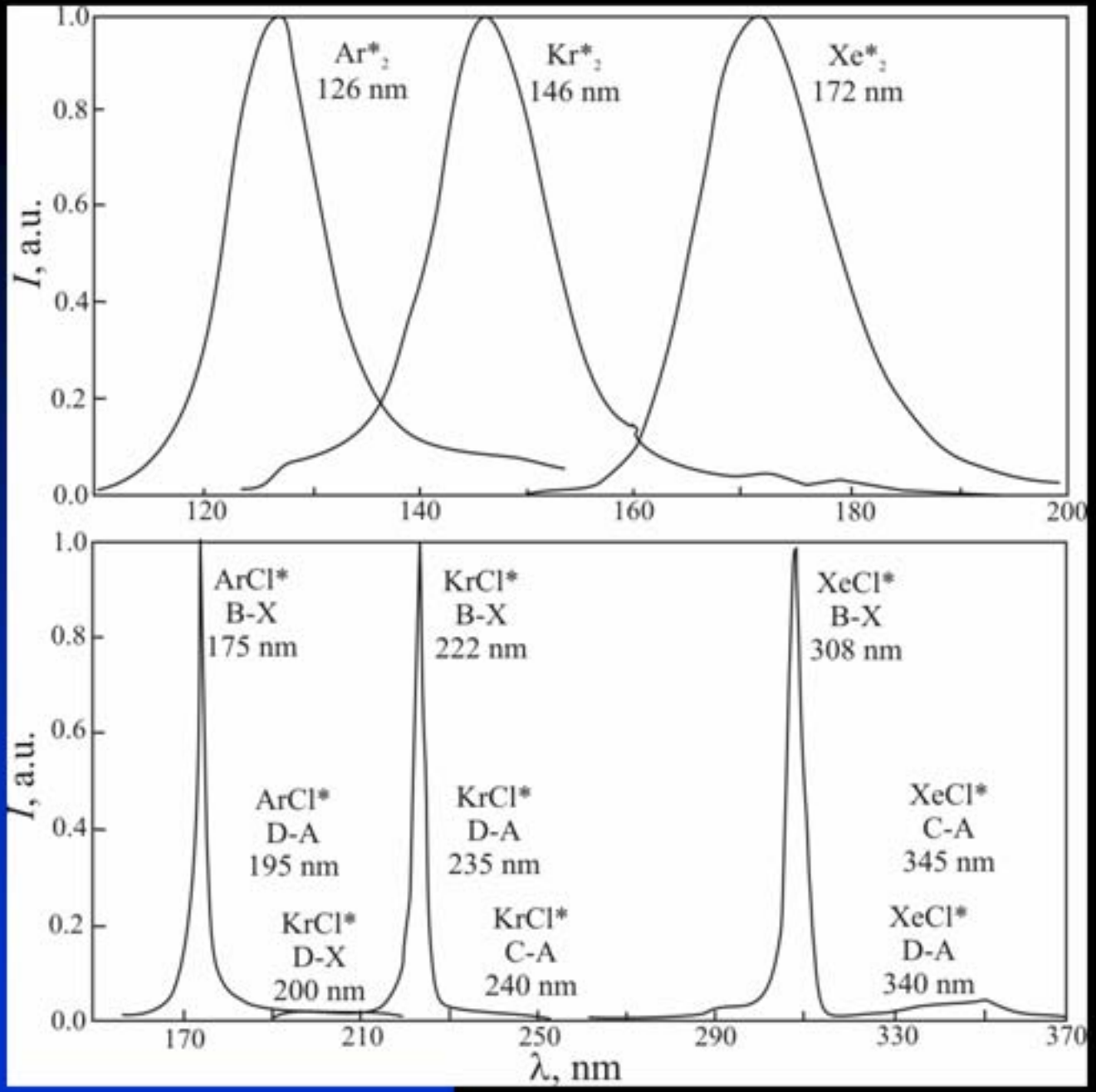
Part 1. Excilamps – What is it?

- Excilamps radiate due to decay of excimer or exciplex molecules. The discharge energy, brought into the gas, transforms into UV radiation with high efficiency (up to 25%) and more than 80% of the overall radiation power of the excilamp can be concentrated in the comparatively narrow (a few nanoseconds at half-height) spectral band of the corresponding molecule.
- For practical application of excilamp, long service life and output radiation stability are required which is provided by barrier-discharge excilamps. For the first time, high-frequency discharge excilamps comprising a radiator of simpler design than barrier-discharge lamps and possessing the longer service life due to absence of working mixture and metal interaction were offered and tested in our investigations in 1999-2006.

Matrix of excimers (X_2^*, Rg_2^*) and exciplexes (RgX^*) obtained from halogens and rare gases and their emission maxima.

Commercially available excilamps are in bold type

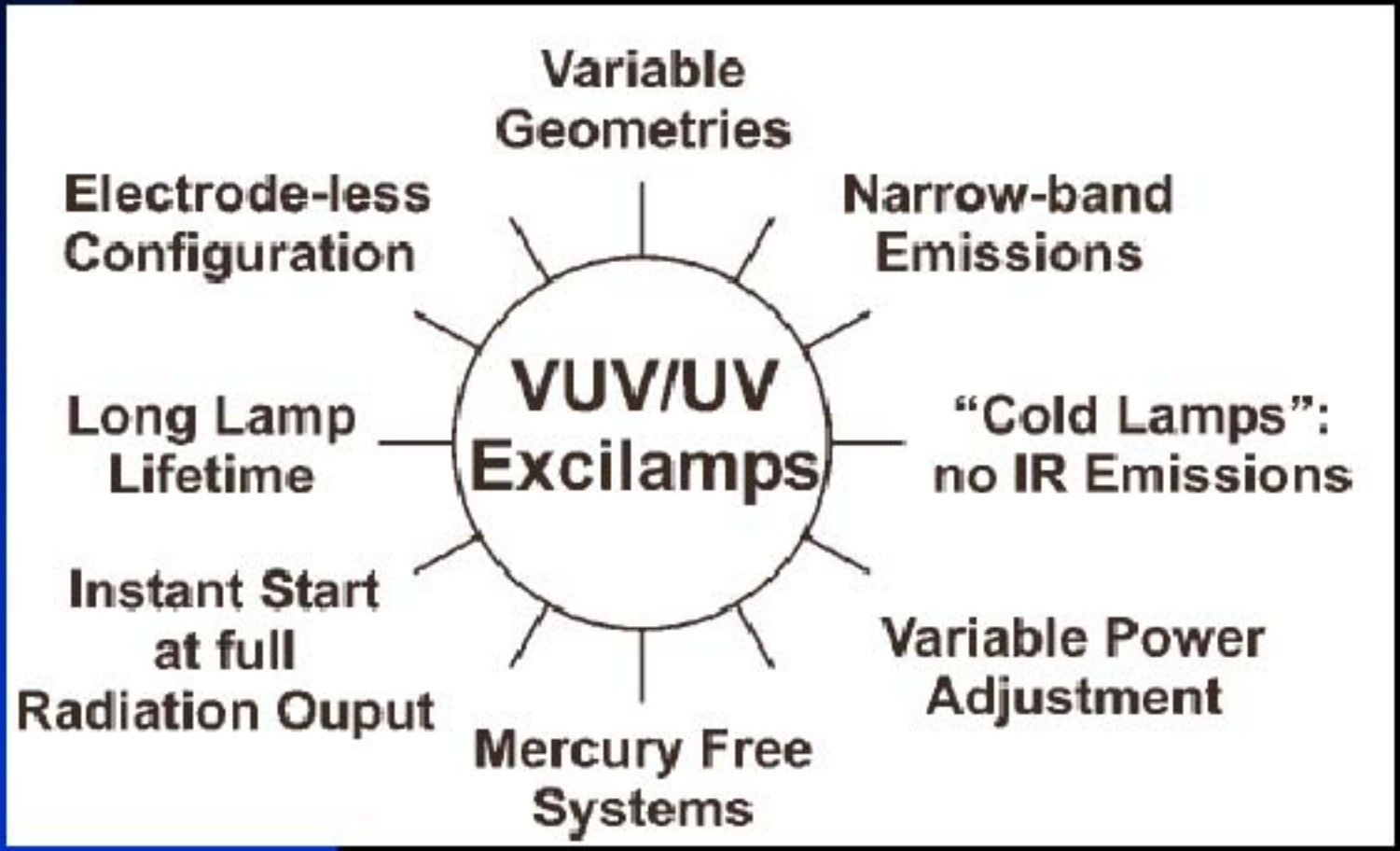
Rare Gas (Rg)			He	Ne	Ar	Kr	Xe
			74 nm	84 nm	**126 nm**	**146 nm**	**172 nm**
	F	157 nm		108 nm	193 nm	248 nm	354 nm
Halogen (X_2)	Cl	259 nm			175 nm	**222 nm**	**308 nm**
	Br	289 nm			165 nm	207 nm	**282 nm**
	I	342 nm				190 nm	253 nm



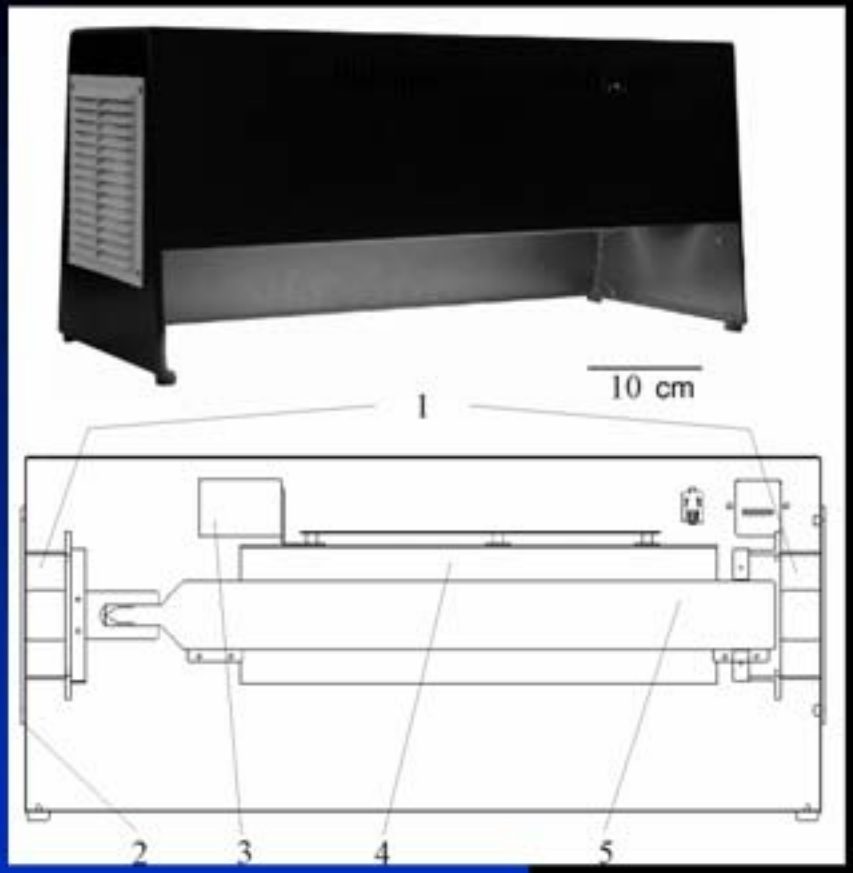
Example of typical emission spectra of rare-gas excimers second continuum obtained in barrier discharge at high pressures (above) and rare-gas halide

exciplexes

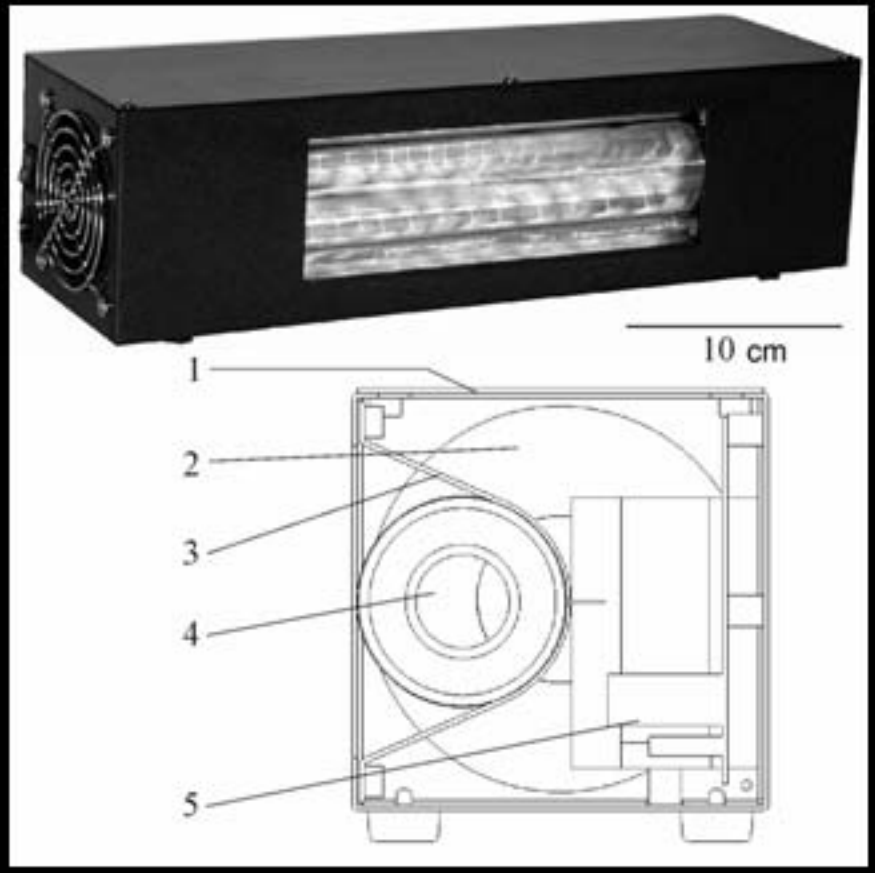
Extraordinary features of modern excilamps



Examples of excilamps

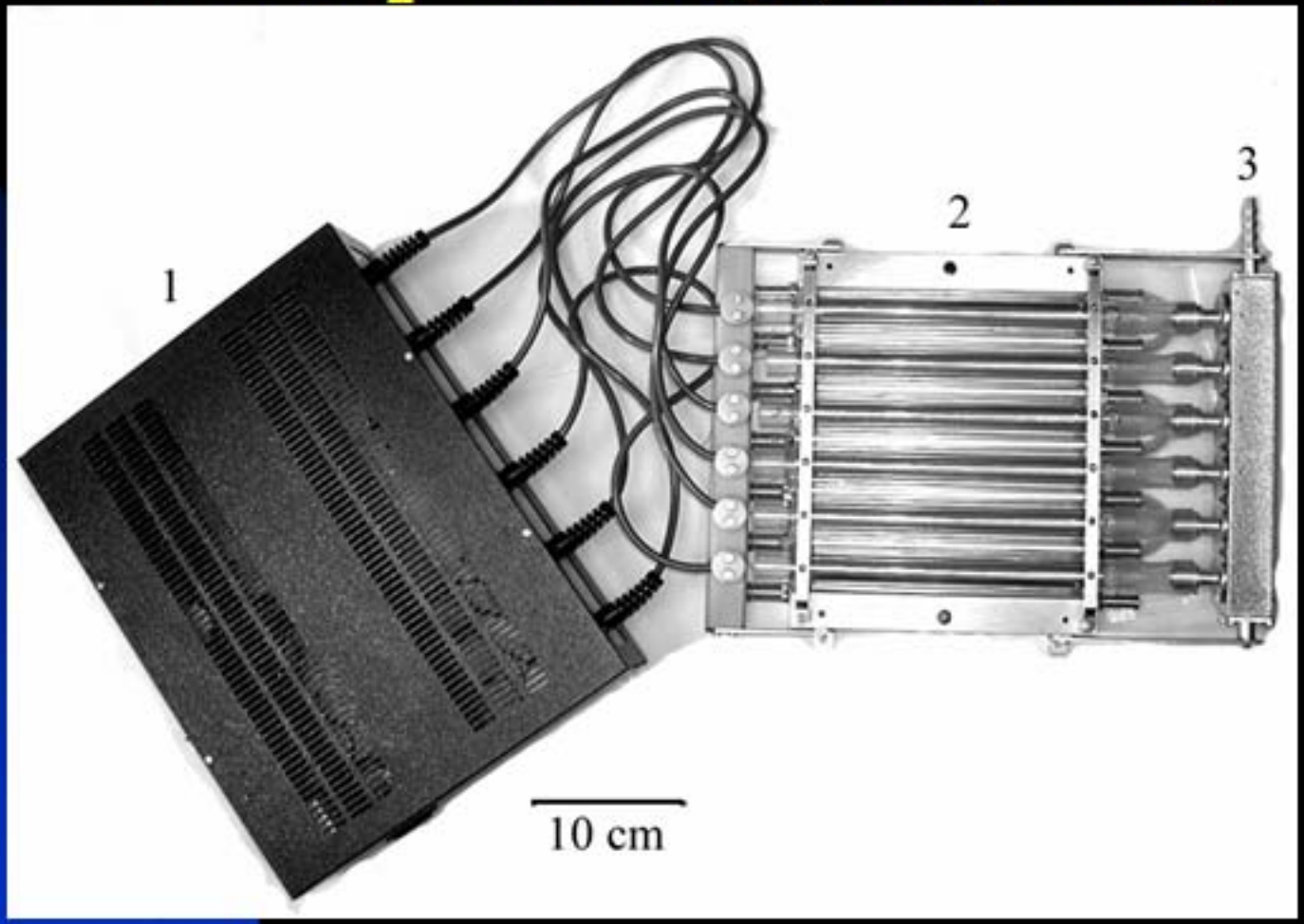


Capacitive discharge excilamp (CD_expand)



Barrier discharge excilamp (CD_compact)

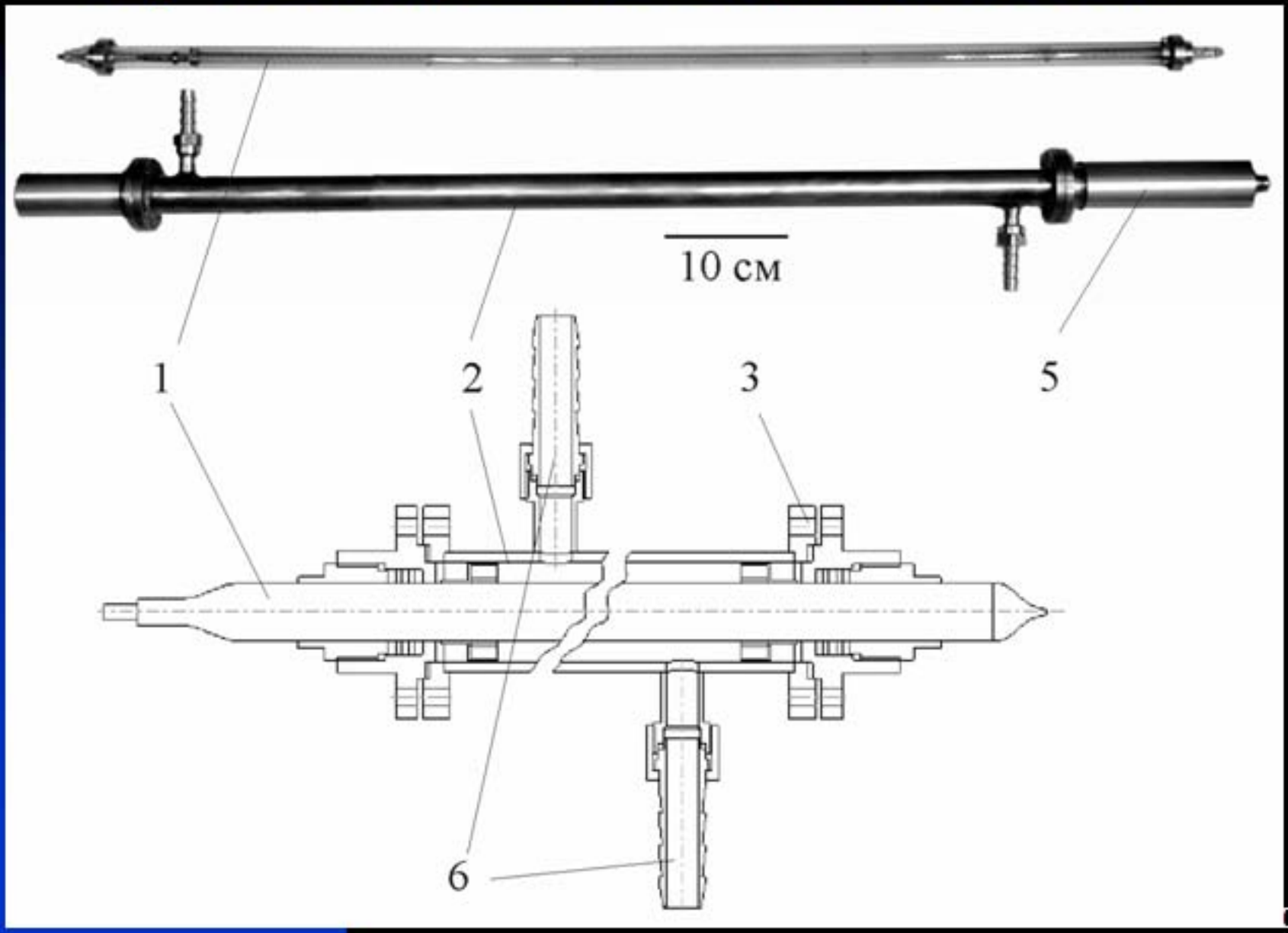
50 W Xe_2* excilamp (BD_power)



General view of DBD-driven Xe_2-excilamp (172 nm, UV radiant power 50 W, radiant emittance 120 mW/cm^2, electrical efficiency 10%): 1 – power supply; 2 – six DBD coaxial bulbs; 3 – cooling system (Model BD_power).

Barrier discharge excilamp (BD_external)

Xe_2^* elevated pressure simple photoreactor



The important characteristics

(1) The working mixture lifetime is at least 1000 h;

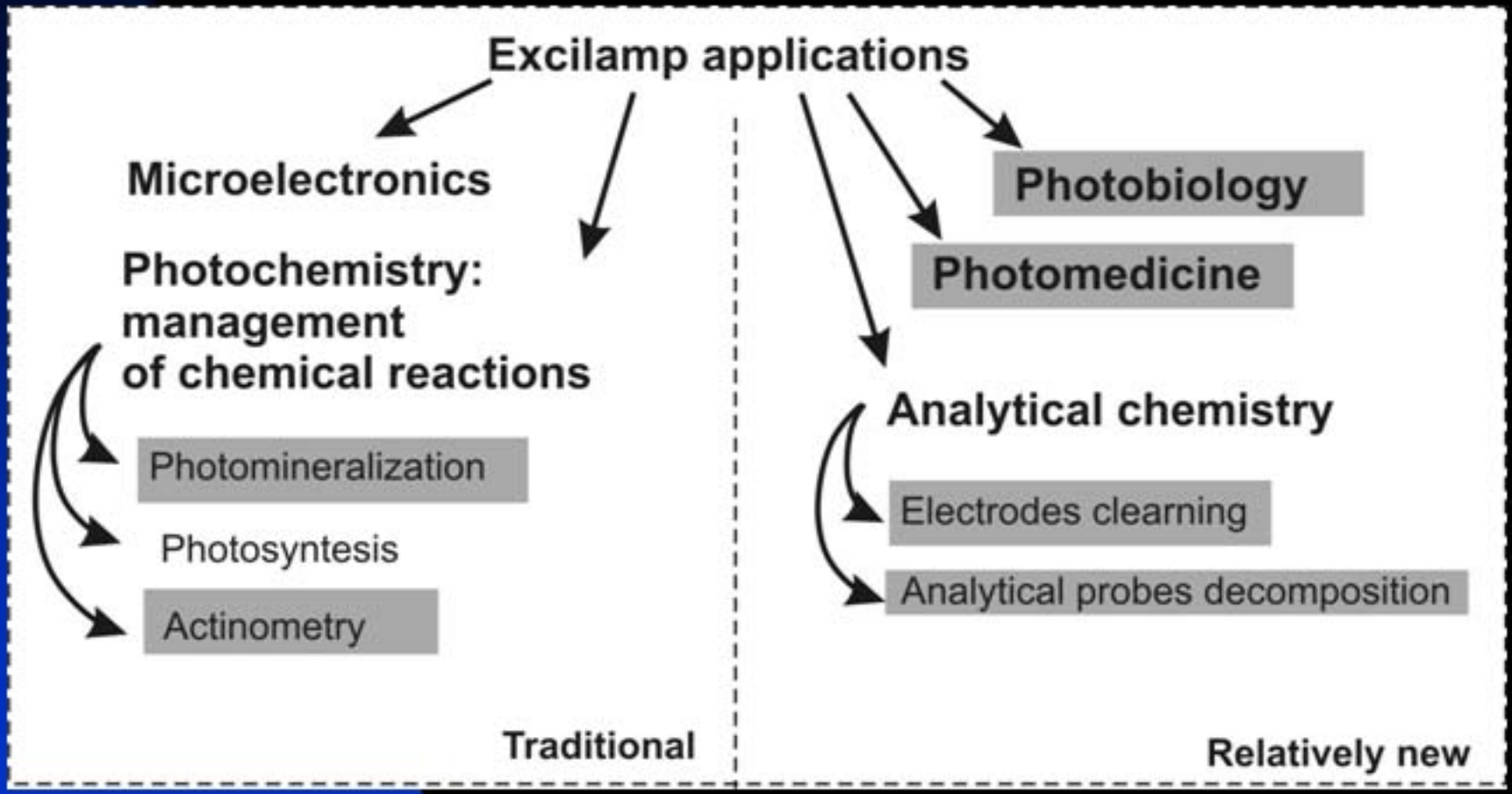
(2) The settling time of stable radiation output mode of the cooled excilamp is ~1 min;

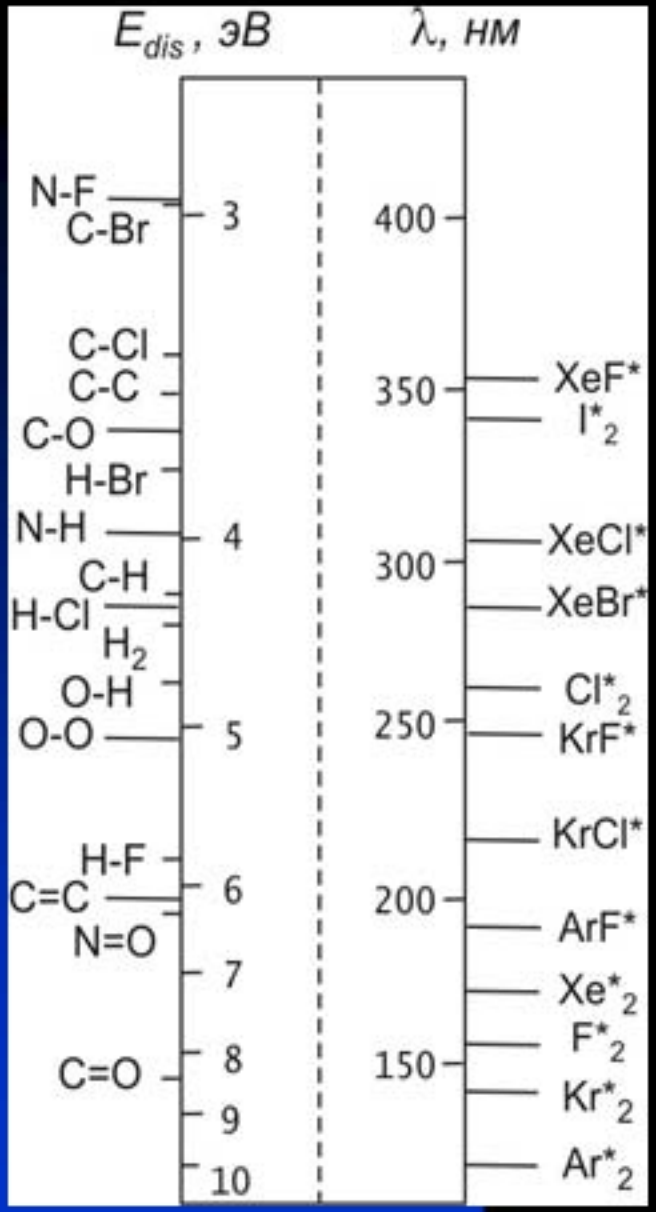
(3) The average radiation power change does not exceed 5% during 24 hours of cooling and is ~10% without cooling; after technological interruption of lamp operation the initial power recovers;

(4) The spread in values of the radiation pulse power density is within 10%.

Thus, excilamps are characterized by high values of efficiency and service life and can be used in microelectronics, biology, medicine, photochemistry, and other spheres of interest.

Part 2. Excilamp Applications



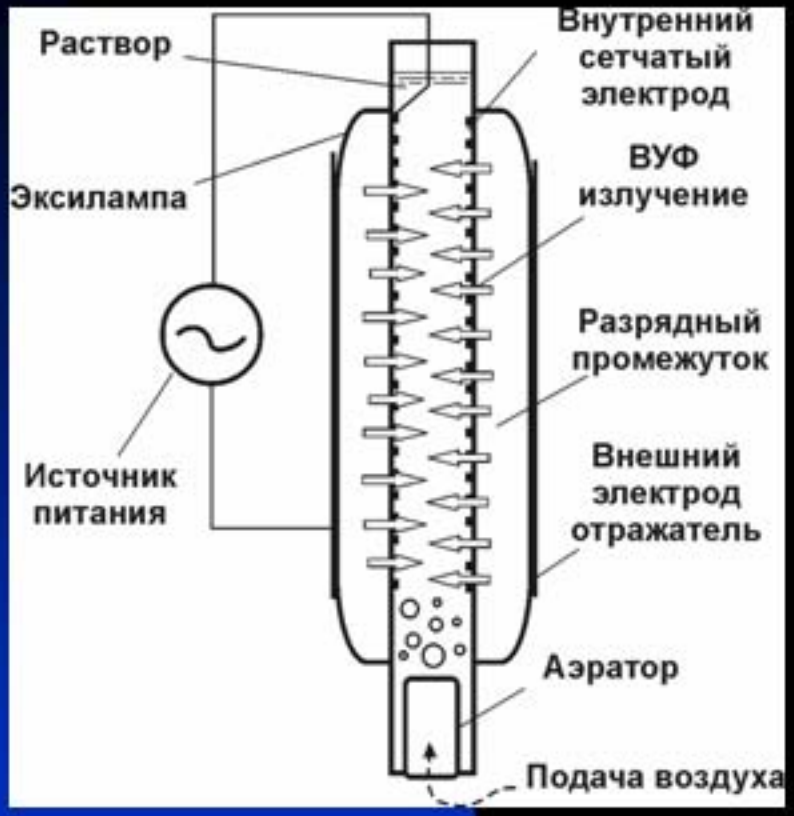


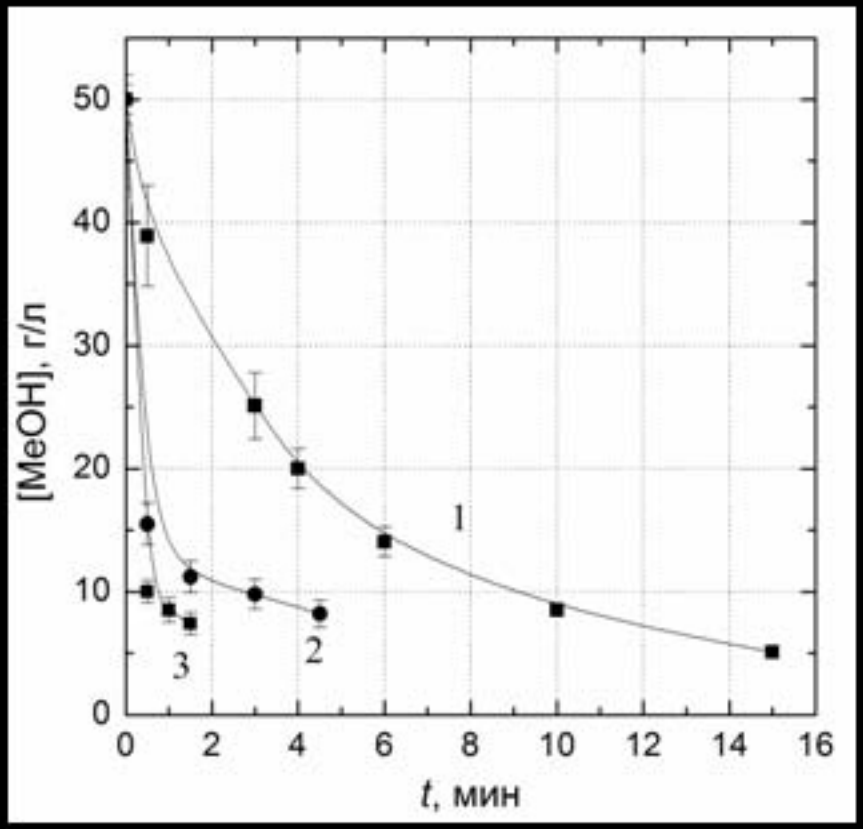
The use of excilamps extends selective effect on photochemical and photophysical systems in the fields where before mercury lamps or excimer lasers were applied.

Dissociation energies of several chemical bonds (left) and corresponding energies of UV/UVU photons of excimer and exciplex molecules (right).

The special characteristics of excilamps led to a renaissance of investigations related to advanced oxidation processes and technologies (AOPs and AOTs)

Methanol photodecomposition in coaxial excilamp





It was shown that with use of Xe_2-excilamp (λ~172 nm) irradiation for MeOH water solutions gives a good results for MeOH photodecomposition and don't' requires additional oxidizers. At the picture – different modes of MeOH irradiation in through-flow coaxial photoreactor.

The removing of water from natural gas at elevated pressures

General view of an elevated pressure photochemistry reactor based on a DBD Xe_2-excilamp (length of excilamp: 120 cm, power consumption: 300W, UV radiation power density: op to 15 mW cm^{-2}, electrical efficiency: 9 – 12%)

Components	Before irradiation	After irradiation
Methane	92.38	92.52
CO_2	0.39	0.39
Ethane	3.48	3.48
H_2O	0.25	0.14
Propane	2.10	2.04
I-butane	0.57	0.55
N-butane	0.52	0.52
I-Pentane	0.16	0.16
N-Pentane	0.11	0.11
C_{6+}	0.04	0.09

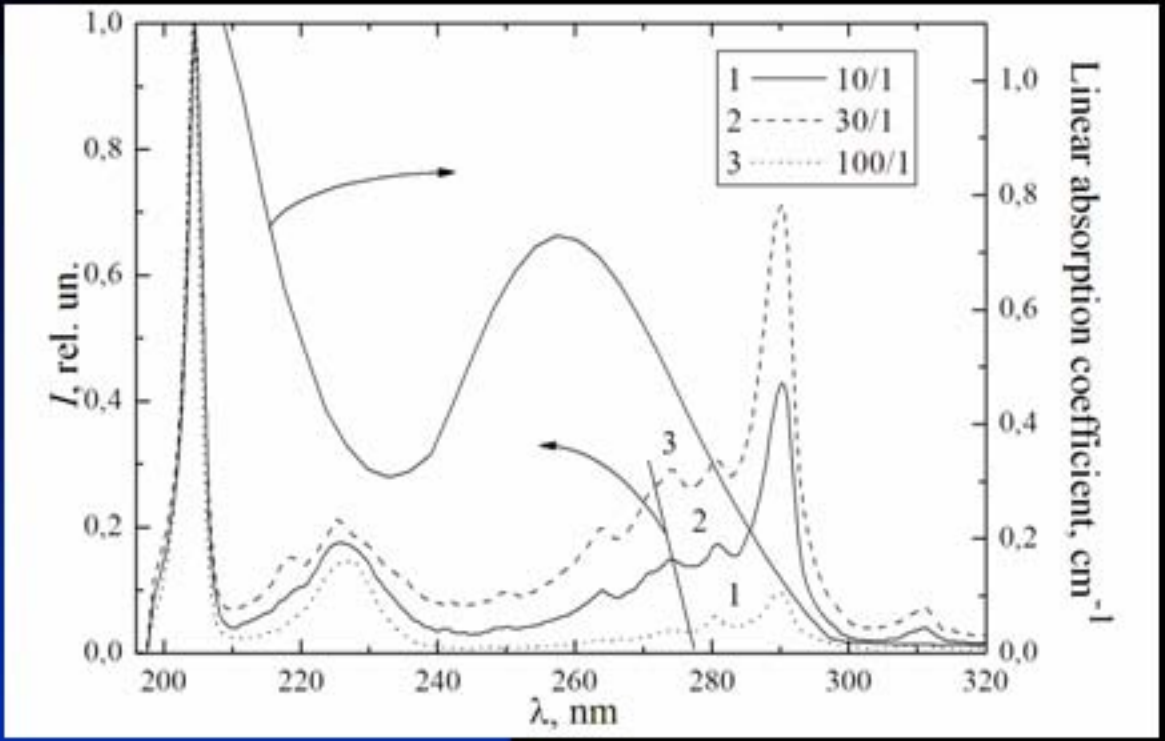
$$C_nH_{2n+2} + \bullet OH \rightarrow \bullet C_nH_{2n+1} + H_2O$$
$$\bullet C_nH_{2n+1} + \bullet C_mH_{2m+1} \rightarrow C_{(n+m)}H_{2(n+m+1)}$$

Applications in photobiology

The main fact is that the different radiation wavelengths are available ***to lead to various biological effects***. Excilamps are suitable for photoinactivation, photoregulation, and photodestruction, allows to carried out selective irradiation of biological objects in those spectrum ranges where its absorption is maximal.

Photoeffect	**Wavelengths**
Inactivation (functional disability), **photodestruction** (destruction)	$\lambda < 300$ nm
Regulation or activation (enhancement or reduction of functional ability)	$\lambda > 300$ nm
Re-activation (restoration of structure and function of biomolecule, being damaged by ionizing radiation or vacuum UV radiation)	$\lambda > 400$ nm

UV Inactivation of Biological Systems by excilamps



Linear DNA absorption coefficient (right axis) and emission spectra of a DBD driven KrBr-excilamp at different partial contents of Kr and Br_2 in the gaseous mixture (left axis).

In the course of investigations we proposed an alternative system – a DBD KrBr-excilamp, which has a combined spectrum of KrBr* (207 nm) and Br_2* (289 nm) molecules; and its bactericidal properties are demonstrated on four test objects

Excilamps in analytical instrumentations

- as instrument for the detection of HDO and H_2O; measurement of particle-bound polycyclic aromatic hydrocarbons (PAHs) in the gas phase;
- organic carbon, nitrogen and phosphorus detection in solutions;
- foodstuff and environmental quality control of toxic element traces.

Part 3. The offers on cooperation in creation of environmentally appropriate technologies based on excilamps

We proposed the development a special excilamps for the areas where relatively narrow band UV radiation is needed:

1. For Advanced Oxidation Processes (AOPs);
2. For Analytical Processes;
3. For UV-disinfection systems;
4. For driving of chemical reactions without adds of chemicals to initial solutions (green photochemistry);
5. For elevated pressure photochemistry.