ATF CO_2 LASER

new developments
near-term plans
technology potentials

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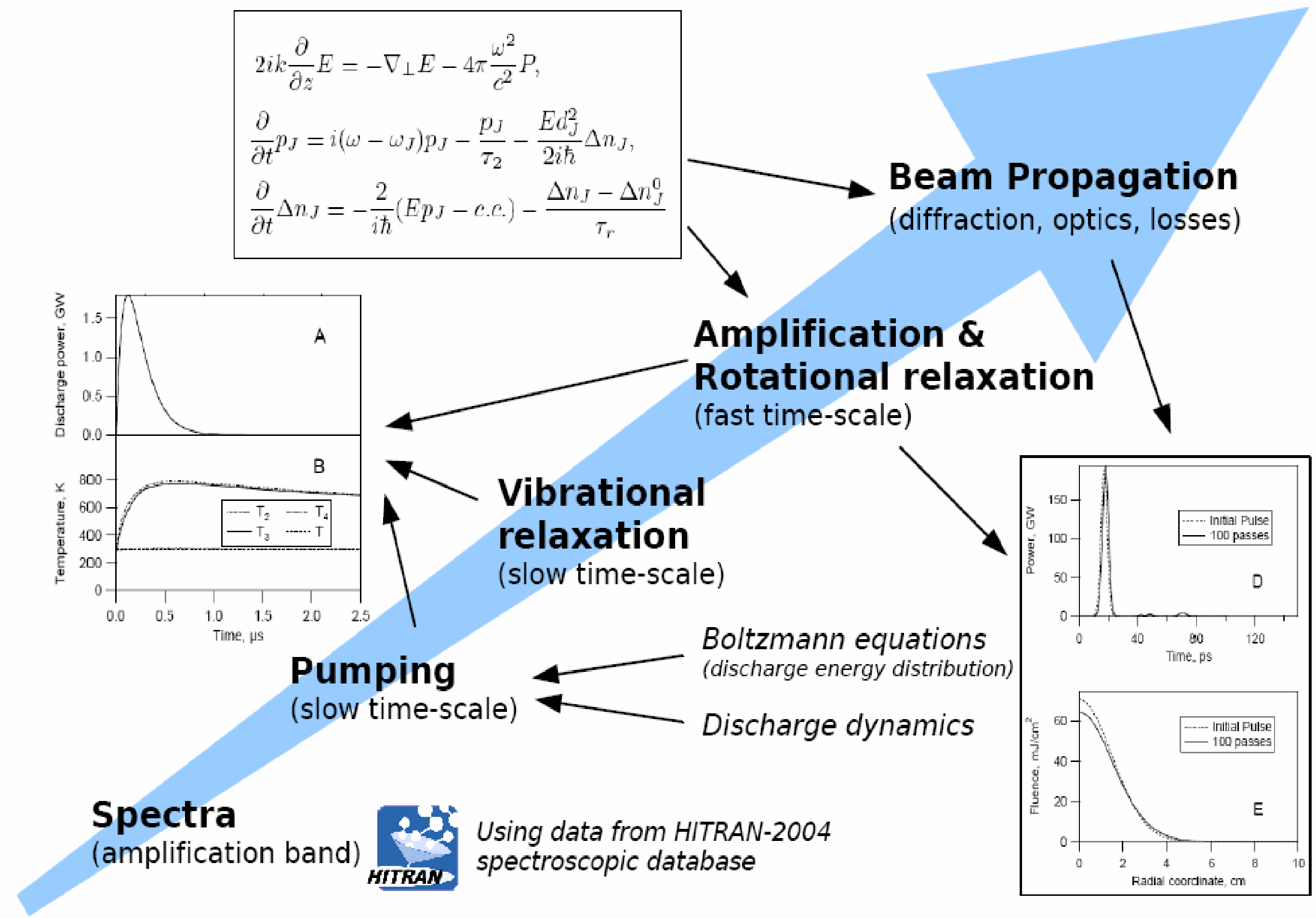
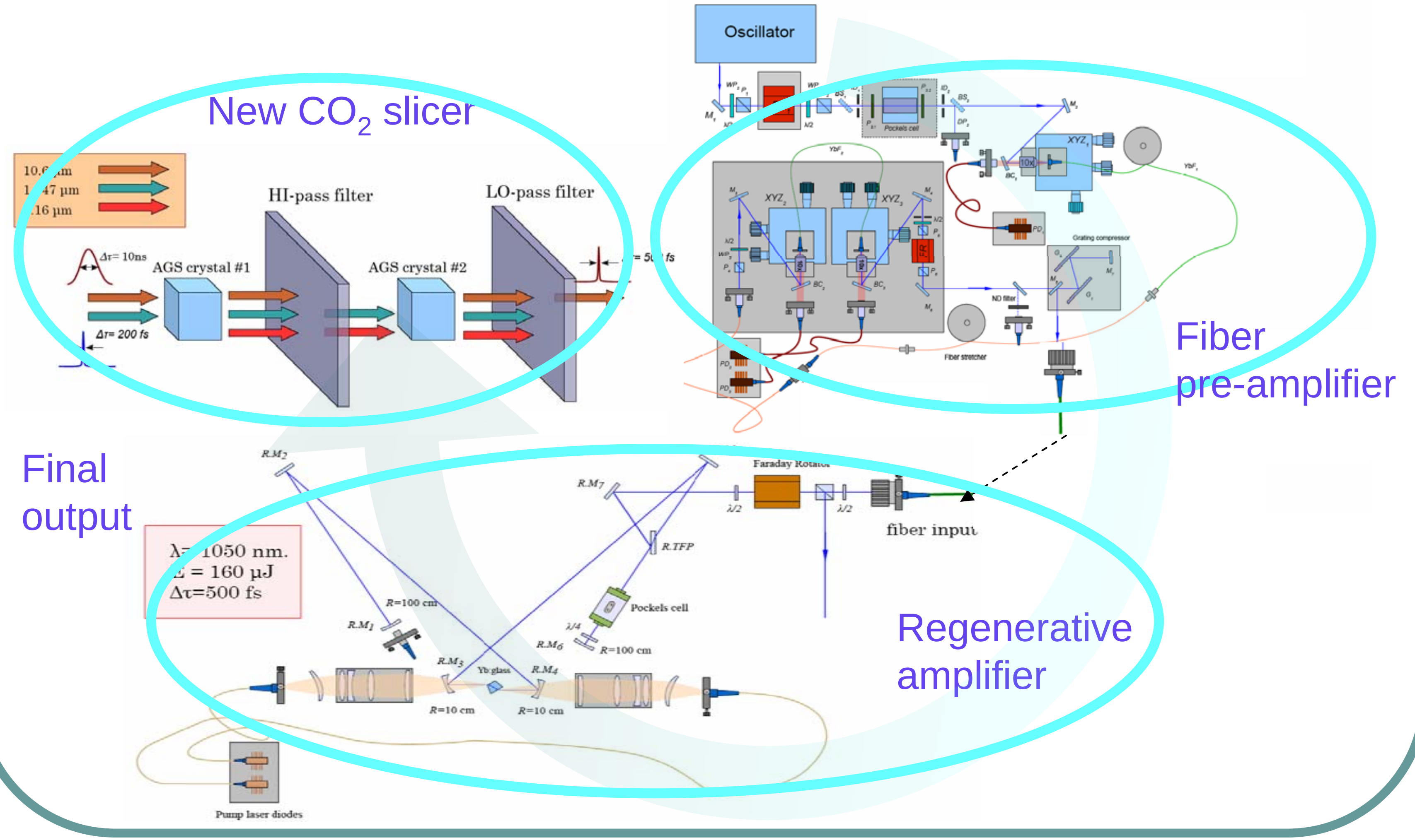
Modeling



$2ik\frac{\partial}{\partial z}E = -\nabla_\perp E - 4\pi\frac{\omega^2}{c^2}P,$
$\frac{\partial}{\partial t}p_J = i(\omega - \omega_J)p_J - \frac{p_J}{\tau_2} - \frac{Ed_J^2}{2i\hbar}\Delta n_J,$
$\frac{\partial}{\partial t}\Delta n_J = -\frac{2}{i\hbar}(Ep_J - c.c.) - \frac{\Delta n_J - \Delta n_J^0}{\tau_r}$
Beam Propagation
(diffraction, optics, losses)
Amplification &
Rotational relaxation
(fast time-scale)
Vibrational
relaxation
(slow time-scale)
Pumping
(slow time-scale)
Boltzmann equations
(discharge energy distribution)
Discharge dynamics
Spectra
(amplification band)
HITRAN
Using data from HITRAN-2004
spectroscopic database
Discharge power, GW
A
B
Temperature, K
T_2
T_4
T_3
T
Time, µs
Power, GW
Initial Pulse
100 passes
D
Time, ps
Fluence, mJ/cm^2
E
Radial coordinate, cm

Femtosecond Yb laser



Near-future plans (as seen in 2007)

- Establish 3-ps TW regime of operation for user's experiments.
- Improve and expand on-line laser diagnostics. (Includes CO_2 autocorrelator modification for short-pulse measurement.)
- Develop techniques for isolating the laser system from parasitic feedback (back reflections) from a target plasma.
- Work on characterizing and controlling the contrast.
- Acquire capability for simulating ps pulse amplification.

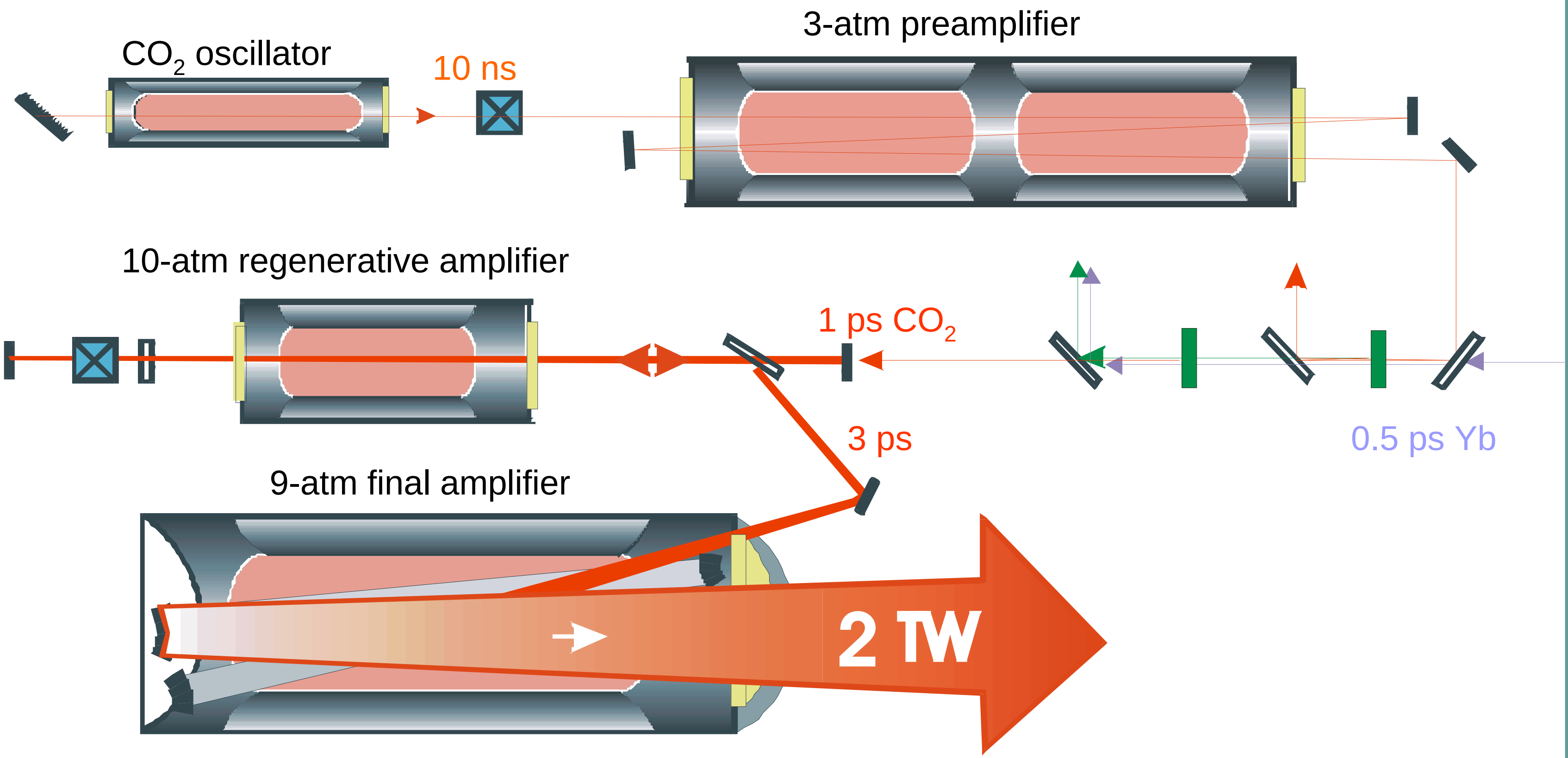
Summarizing progress since User's Meeting 2007

- Better laser characterization and understanding through:
  - New simulation capability
  - New pulse diagnostic
- Improvements in a pulse structure (changed line, etc.)
- Multi-pulse trains for high-rep-rate gamma sources
- New results in user's experiments:
  - First LACARA acceleration
  - Demonstration of quasi-monoenergetics MeV protons
  - Successful Compton runs
  - Approach to high-repetition-rate gamma sources
- Decisive steps towards the 1-ps multi-Terawatt regime via a new solid state laser and isotopic upgrade

Near-future plans

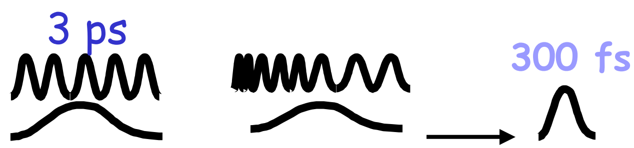
- Establish multi-terawatt regime by completing tasks:
  - Put in operation a new femtosecond laser and 1-ps CO_2 pulse slicing system synchronized with linac.
  - Operate regenerative amplifier with mult-isotope gas to avoid pulse splitting.
- Comprehensive on-line laser diagnostic.
- Contrast (10^3 for ps pre-pulse, 10^6 for ns pre-pulse).
- Simulation of multi-terawatt regimes and chirped pulse compression.
- Improved multi-pulse train regime with isotopes.

CO_2 laser system
Upgrade to 2 TW, 3 ps pulses



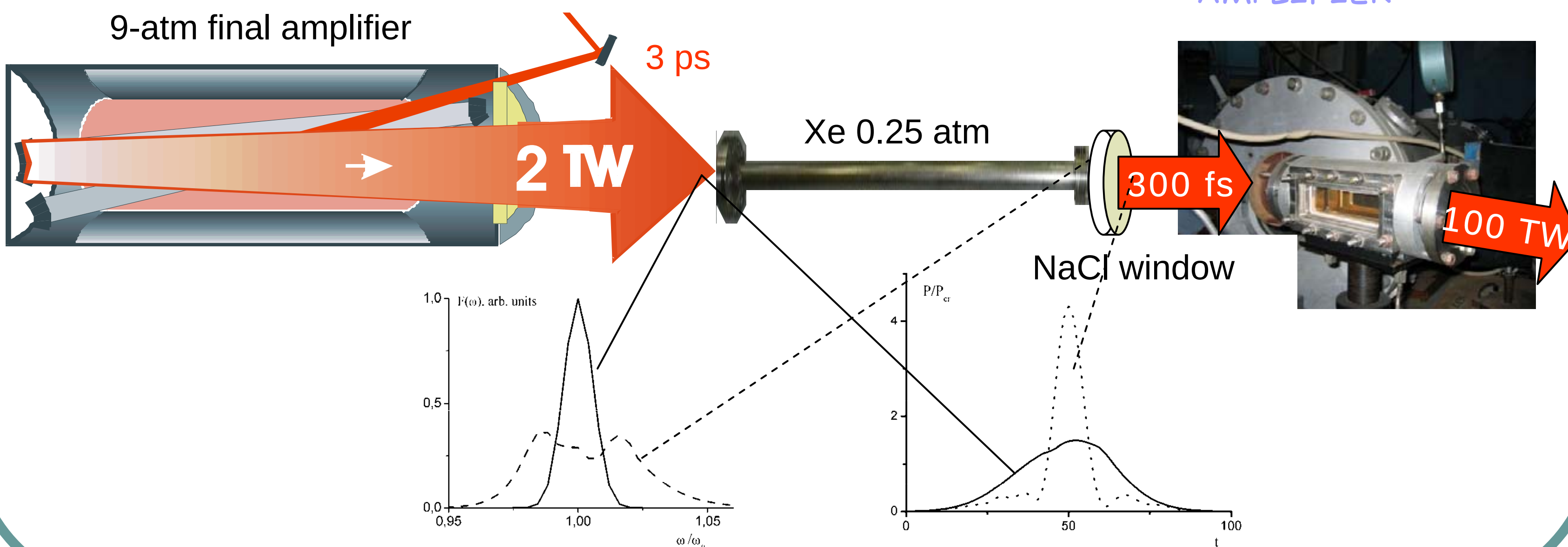
Prospective setup with chirping and compression

Laser-induced ionization shifts the phase of the wave resulting in a chirp and subsequent pulse compression



$$\Delta\omega = \frac{\pi n_e^0}{\lambda n_{cr}} \frac{\partial}{\partial t} \int n_e(t,x)dx$$

OPTICALLY-PUMPED MULTI-ISOTOPE AMPLIFIER



CO_2 laser for plasma accelerators

Ponderomotive force
drives plasma wave

$$m\frac{d\mathbf{U}}{dt} = -e\nabla\Phi_{\mathrm{pond}},$$

The ponderomotive energy of the electron in the optical field is proportional to λ^2.

CO_2 laser will produce 10 times bigger bubble, 10 times higher charge, and better control over e-beam parameters and phasing between accelerator stages.