Competitiveness Operational Programme (COP)

Extreme Light Infrastructure - Nuclear Physics (ELI-NP) – Phase II

Simulating the behavior of HPLS

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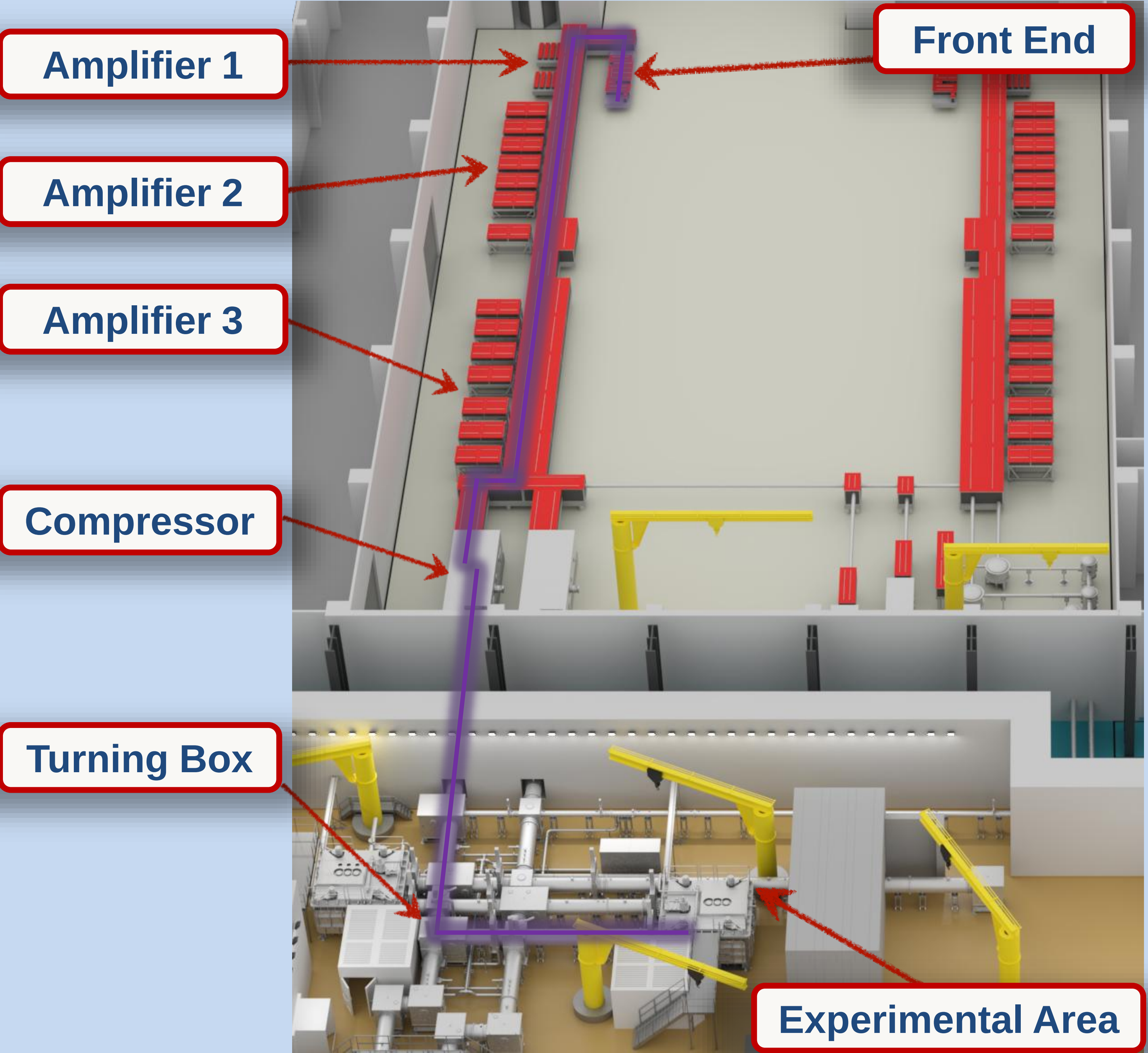


Front End

0.19 mJ
1.8 mm

Amplifier 1.1

25 mJ
1.8 mm

Amplifier 1.2

1.9 J
21 mm

Amplifier 2

30 J
55 mm

Amplifier 3.1

114 J
95 mm

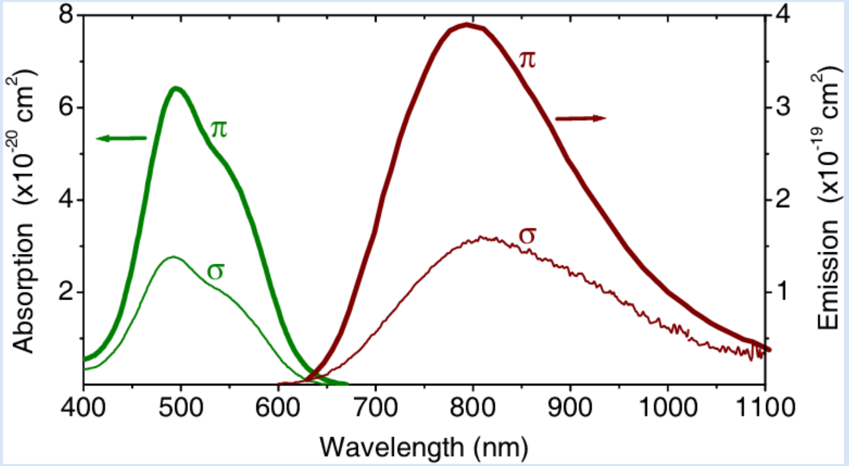
Amplifier 3.2

334 J
150 mm

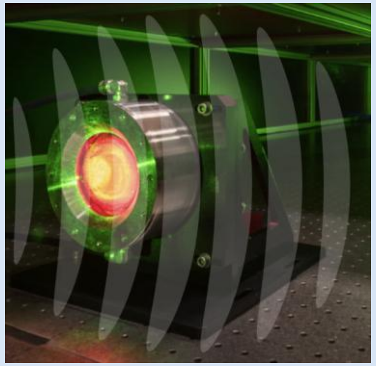
Compressor

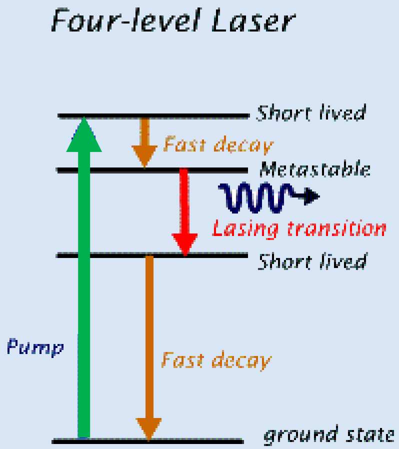
246 J
500 mm

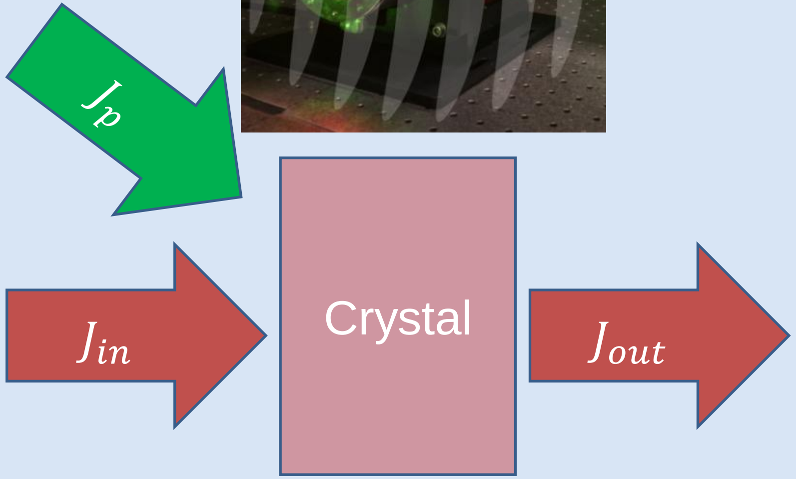
Integration of Franz-Nodvik model for high power solid-state amplifiers



- Building a basic model of Laser amplification for 10 PW configuration.
- Improving the fidelity of each amplifier by corelating real energy measurements with simulated data.







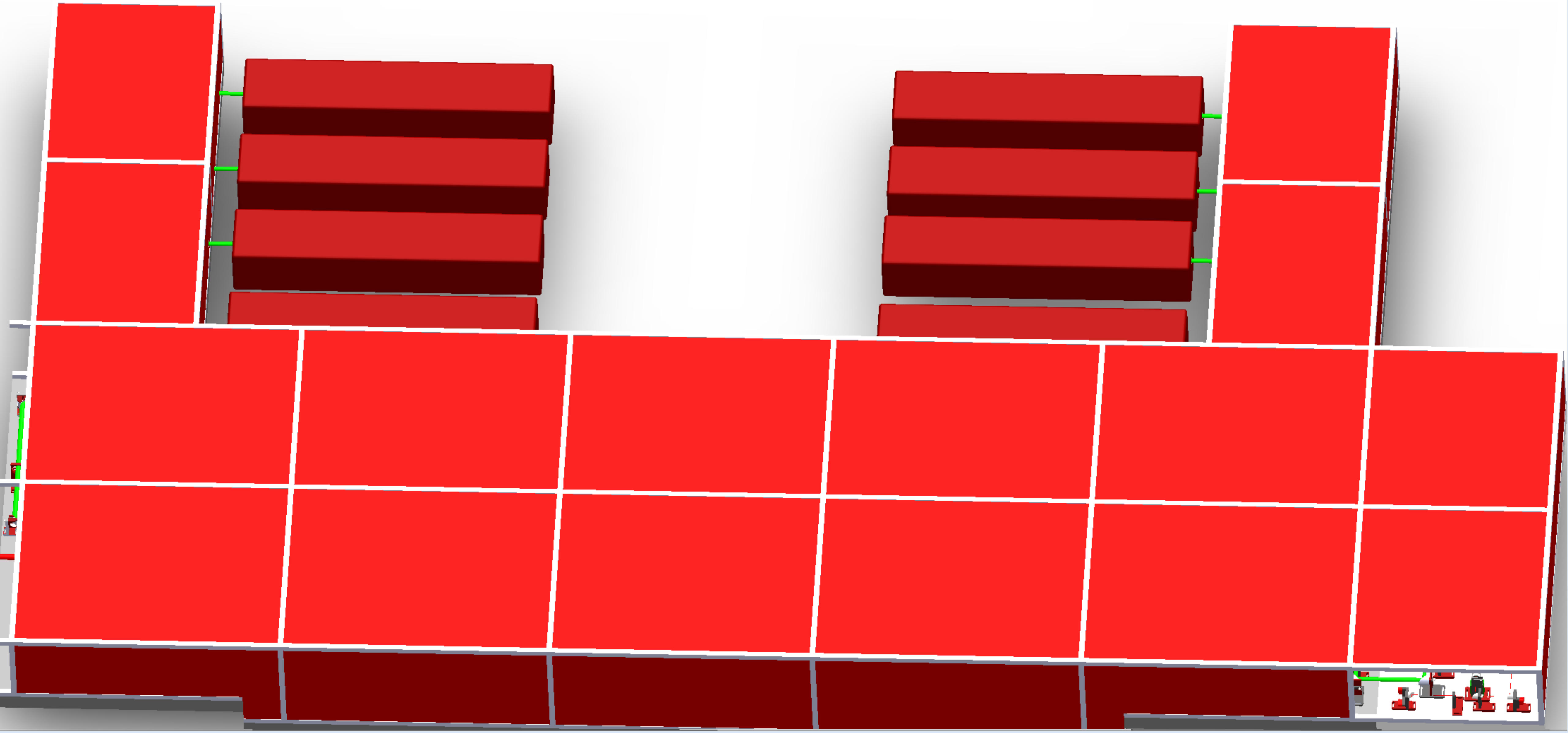
$$J_{in} = \frac{E_{in}}{\pi r^2}$$

$$J_{stock} = K_{eff} Abs \frac{\lambda_p}{\lambda_{in}} \frac{E_p}{\pi r^2}$$

$$J_{out} = J_{in} G_E = J_{sat} \ln\left\{1 + \left[\exp\left(\frac{J_{in}}{J_{sat}}\right) - 1\right] \exp\left(\frac{J_{stock}}{J_{sat}}\right)\right\}$$

$$J_{sat} = \frac{hc}{\lambda \sigma(\lambda)}$$

$$J'_{stock} = J_{stock} - (J_{out} - J_{in}) + SecJ_{stock}$$



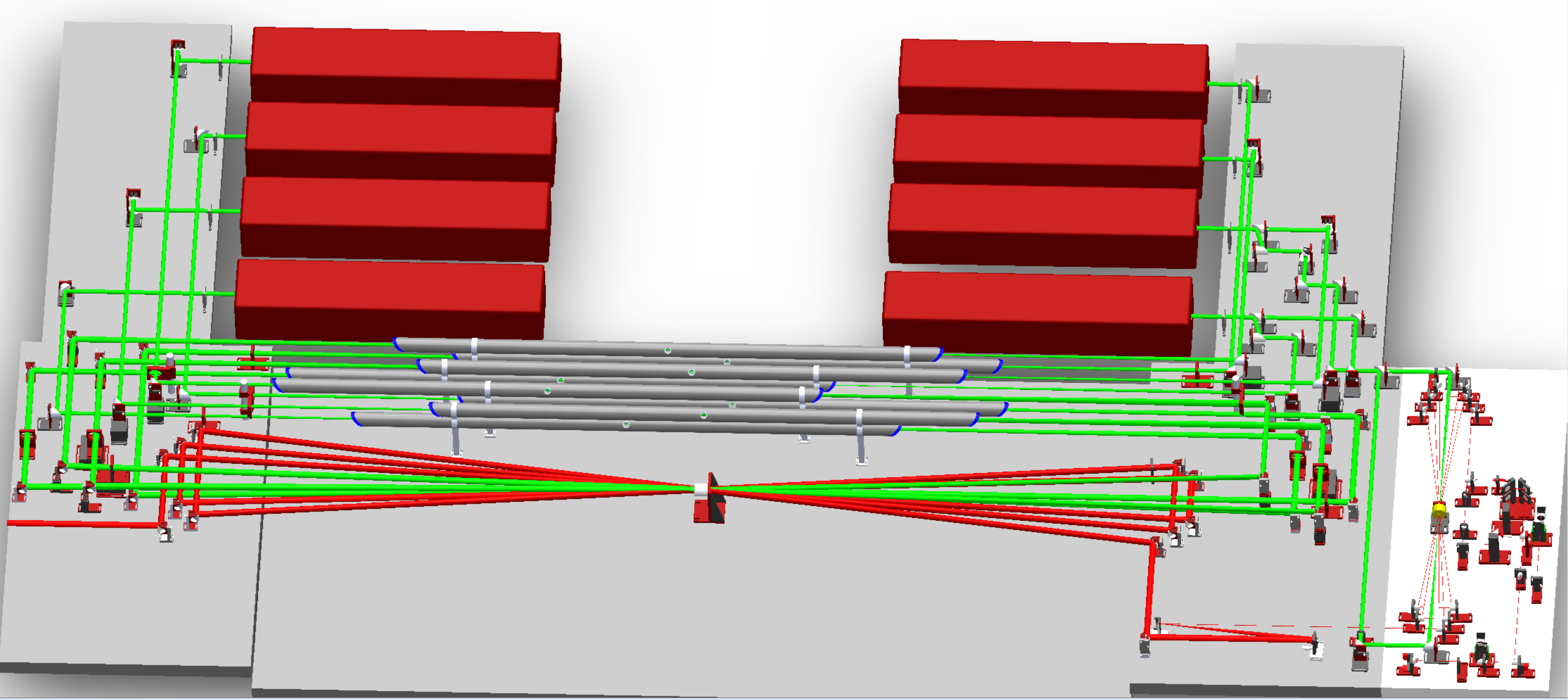
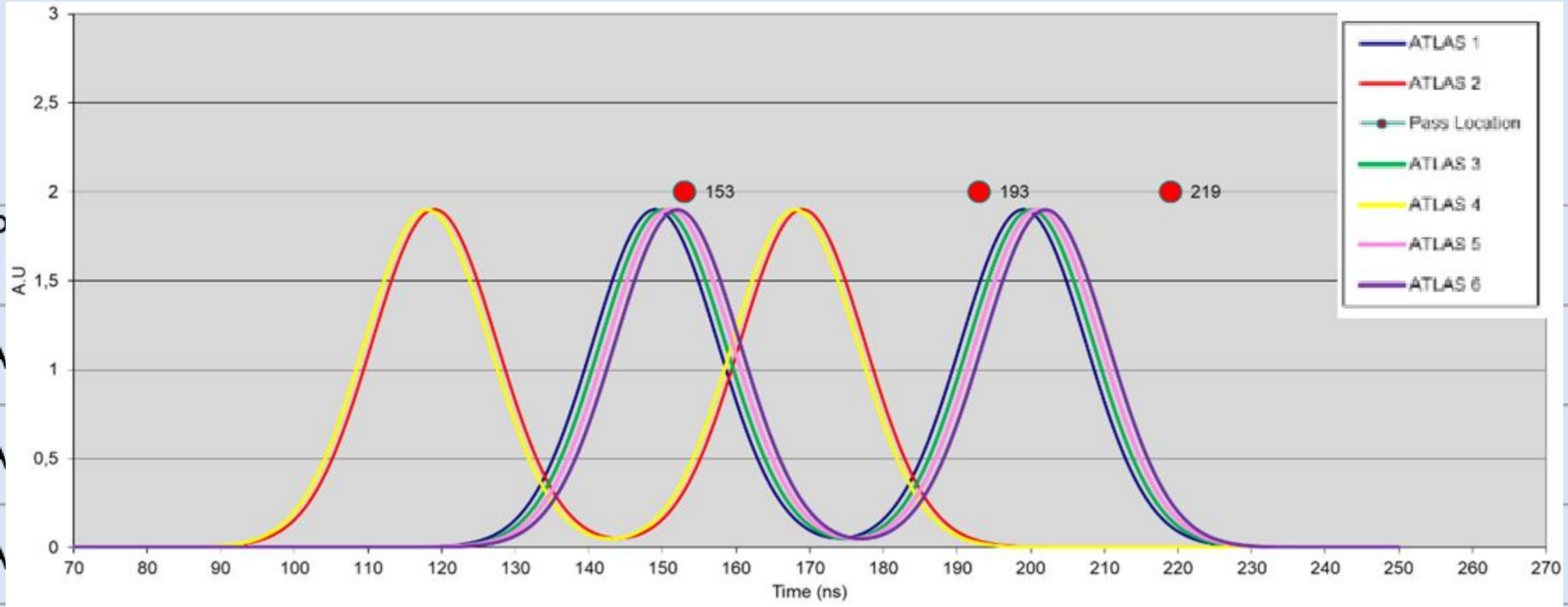


Table of laser system parameters

Amplifier No.	Wp(λ)	Win(λ)	Ep (J)	Din(cm)	Dp(cm)	Keff	Fsat	Abs	Loss	Passes
1.1	532	800	0.082	0.19	0.213	0.9	0.93	0.9	0.925	5
1.2	532	800	8.25	2.6	2.43	0.94	0.96	0.95	0.85	5
2	532	800	85	5.5	5.63	0.9	0.92	0.9	0.94	3
3.1	527	800	179	9	9.1	0.9	0.9	0.93	0.94	3
3.2	527	800	530	14	14	0.9	0.9	0.93	0.955	3



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Building a

[0.064 ...] Amp 1.2

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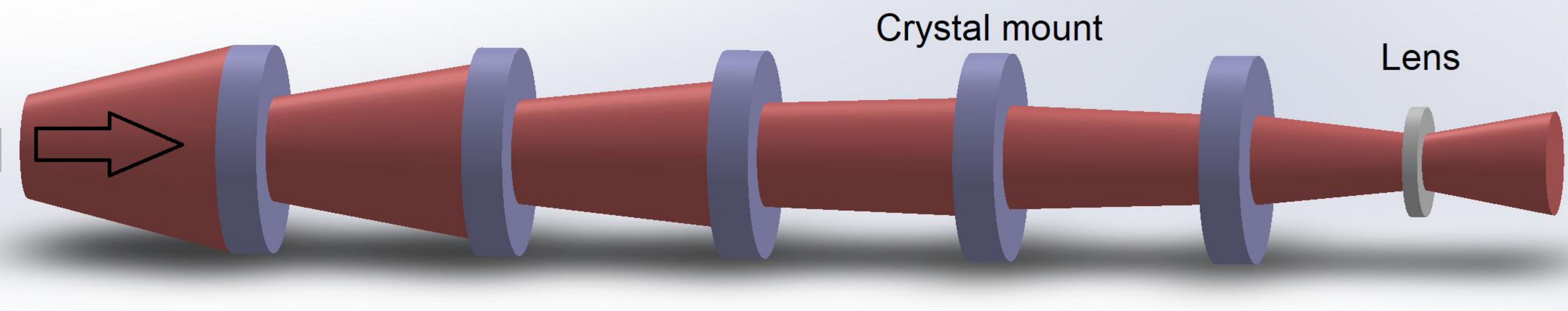
Amplifier No.	Amp 1.1 Measurements (J)	Amp 1.1 Best Simulation (J)	Amp 1.2 Measurements (J)	Amp 1.2 Best Simulation (J)
Pump energy	0.082	0.082	9.89	9.89
Seed Pass 0	1.9E-04	1.9E-04	0.021	0.021
Seed Pass 1	6.5E-04	6.7E-04	0.064	0.064
Seed Pass 2	2.1E-03	2.2E-03	0.222	0.15
Seed Pass 3	6.3E-03	6.5E-03	0.581	0.39
Seed Pass 4	1.5E-02	1.5E-02	1.64	1.63
Seed Pass 5	2.4E-02	2.4E-02	3.1	3.13
Best Cost	5.5E-08		4.2E-02	
	Amp 1.1 Input Range	Amp 1.1 Best parameters	Amp 1.2 Input Range	Amp 1.2 Best parameters
D_{in}(cm)	0.16 - 0.27	**0.186**	2.2 - 2.5	**2.17**
D_p(cm)	0.19 - 0.27	**0.228**	2.3 - 2.6	**2.382**
J_{sat} (J/cm^2)	0.84 - 0.99	**0.992**	0.85 - 0.94	**0.82**
A (%)	0.87 - 0.95	**0.888**	0.85 - 0.96	**0.845**
L (%)	0.75 - 0.98	**0.968**	0.86 - 0.98	**0.84**

Modeling thermal lens of amplifiers

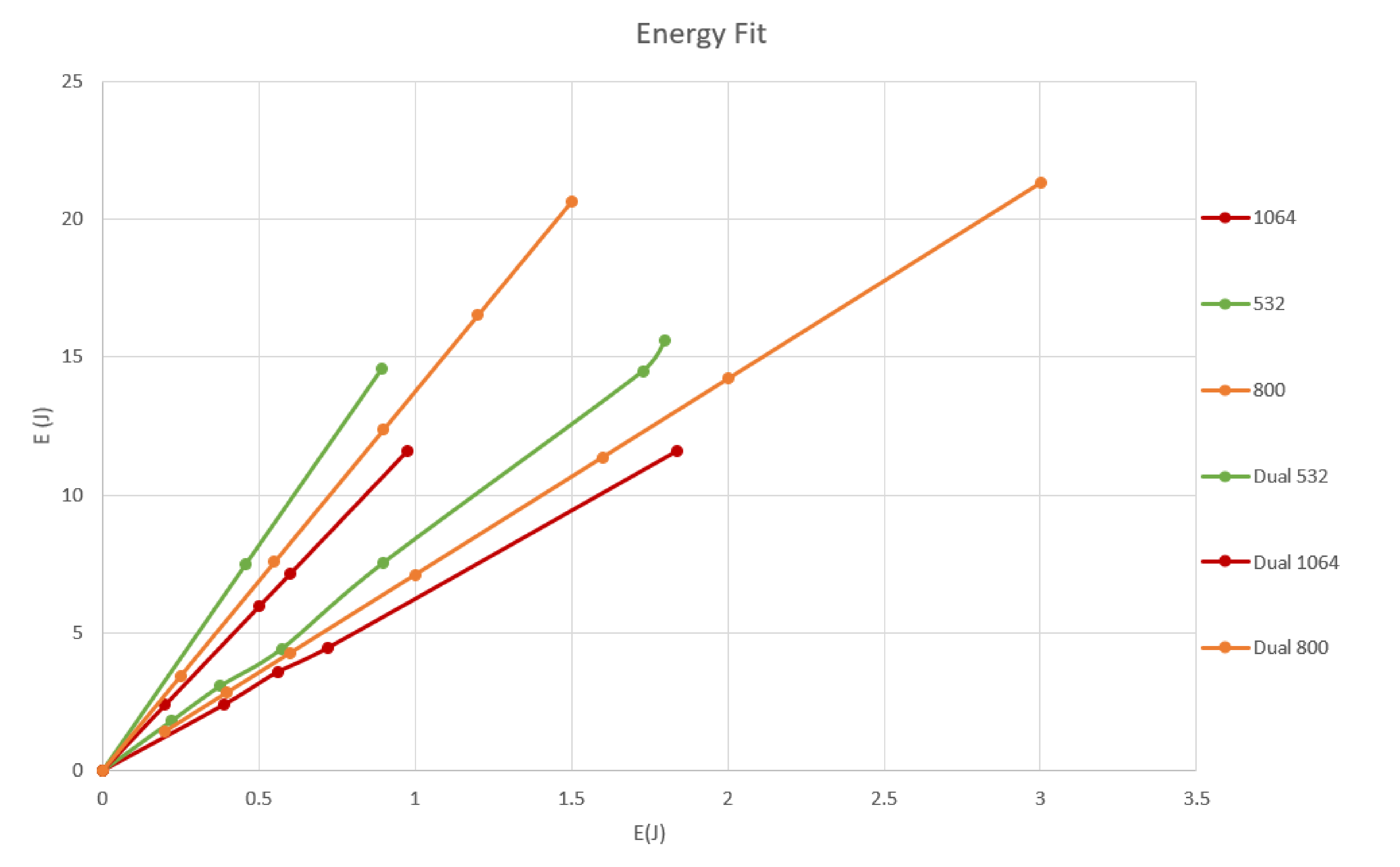
FOCAL LENS CALCULATOR				
Thermo-optic coeficient-dn/dT (K-1)	1.4E-05		SAGA 1	1.2
Thermal conductivity (W/(cm K))	0.4		SAGA 2	1.29
Beam Diameter (cm) / Area (cm2)	2.52	4.988	SAGA 3	1.25
Pump Power (W) / Absorbed power	98.9	89.01	SAGA 4	1.2
Absorbtion coeficient Abs	0.9		SAGA 5	1.2
Focal Length f (m)	**32.019**		SAGA 6	1.25
			SAGA 7	1.2
DIVERGENCE CALCULATOR			SAGA 8	1.3
Diameter 1 (cm)	5.08			
Diameter 2 (cm)	6.615			
Length (m)	3.838			
Divergence Half-angle (mrad / deg)	**2.000**	**0.1146**		
Pump Diameter	2.7			
Angle deviation 1 pass (mrad / deg)	**0.422**	**0.0242**		

$$f = \frac{2kA}{\frac{\partial n}{\partial T} P_{heat}}$$

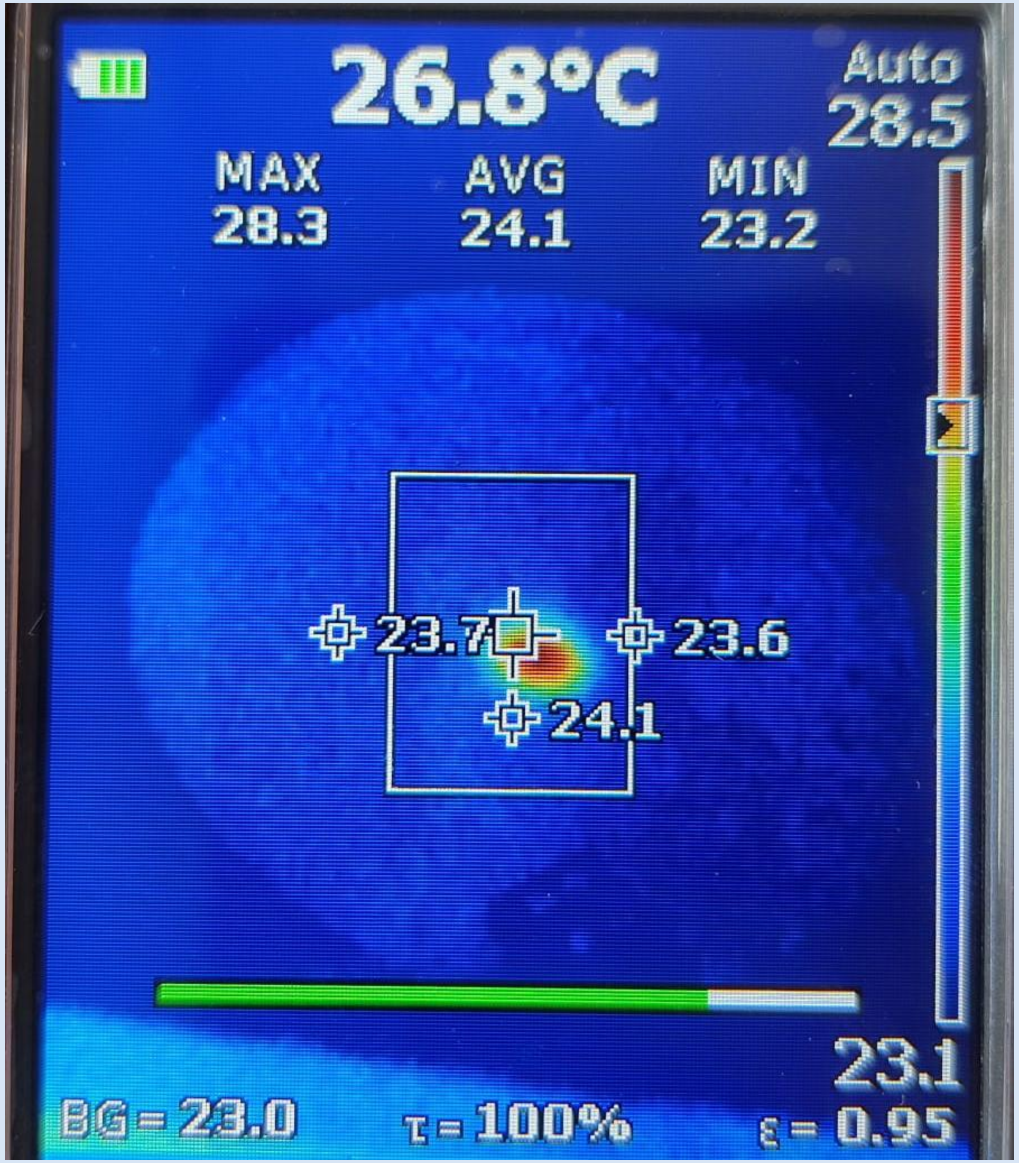
	Beam Div (mrad)	I Diam (cm)	Effective Div(mrad)	Diameter(cm)	Loss
Pass 1	1.7	2.52	1.4344	3.2	0.712
Pass 2	1.013	2.70	0.7819	3.497	0.596
Pass 3	0.360	2.70	0.3262	2.982	0.820
Pass 4	-0.095	2.70	-0.0954	2.626	1.057
Pass 5	-0.517	2.63	-0.5170	2.214	1.487



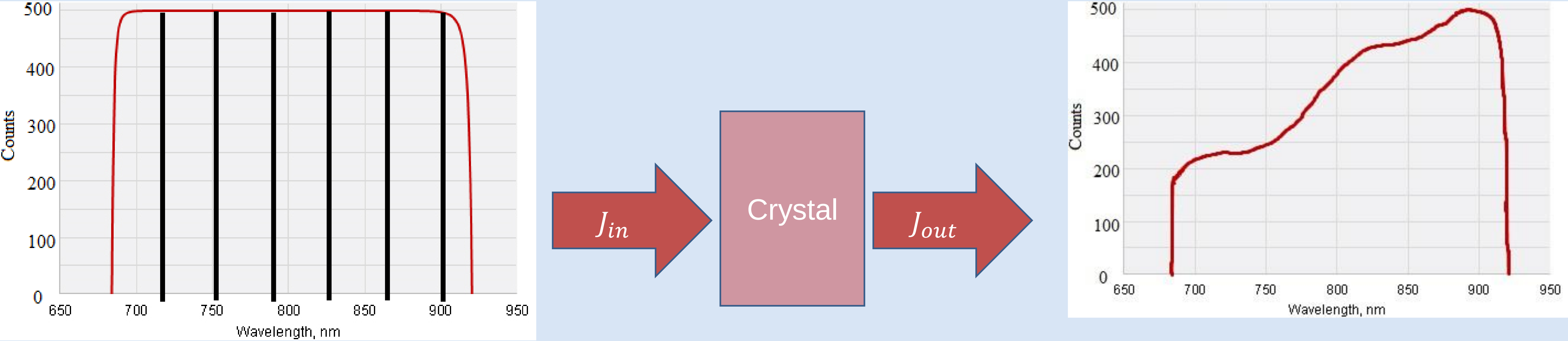
Active measurement: Calibrating energymeters with sheet of spectralon



Passive measurement with thermal camera



Spectral analysis



Applications

Modeling amplifier for ARM C in HPLS

Aim:

- Model amplifiers to achieve 100 TW on target
- Explore different variations of amplifiers while leveraging reliability and cost

Constrains:

- Limited pump energy
- Limited seed energy
- Thermal lens
- B-integral

Scenario		Seed [J]	Pump [J]	D_{in} [cm]	D_p [cm]	Passes	Output[J]
Default		0.021	9. 72	2.344	2.36	5	3.1
Fixed thermal lens	Default	0.021	9. 72	2.344	2.36	5	3.4
	Strong pump	0.021	11	2.344	2.36	5	4.55
	Improved seed from FE	0.04	9. 72	2.344	2.36	5	3.8
	Improved seed FE and strong pump	0.04	11	2.344	2.36	4 / 5	4.01 / 4.7
	Seeded from Amplifier	1	9.72	2.344 / 2.55	2.36 / 2.6	3	5.13 / 4.7
With Thermal lens	Improved seed from Front-End	0.04	9.72	2.344	2.36	5	3.7
	Seeded from Amplifier	1	9.72	2.344	2.36	3	4.2
	Strong pump	0.021	11	2.344	2.36	3	4.41

Conclusions

- We presented a successful integration of Frantz-Nodvik equations in a model of our HPLS.
- We have successfully overlapped the physical behavior of HPLS with the simulation both in energy and spectral domain.
- We have utilized creative ways to measure highly diverse beam parameters.
- We utilized these tools to analyze HPLS behavior under different operating scenarios to determine the most efficient and safest way of operation.
- We have demonstrated the capability to design laser systems in-house.

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We want contrast measurements prior to beam delivery!
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