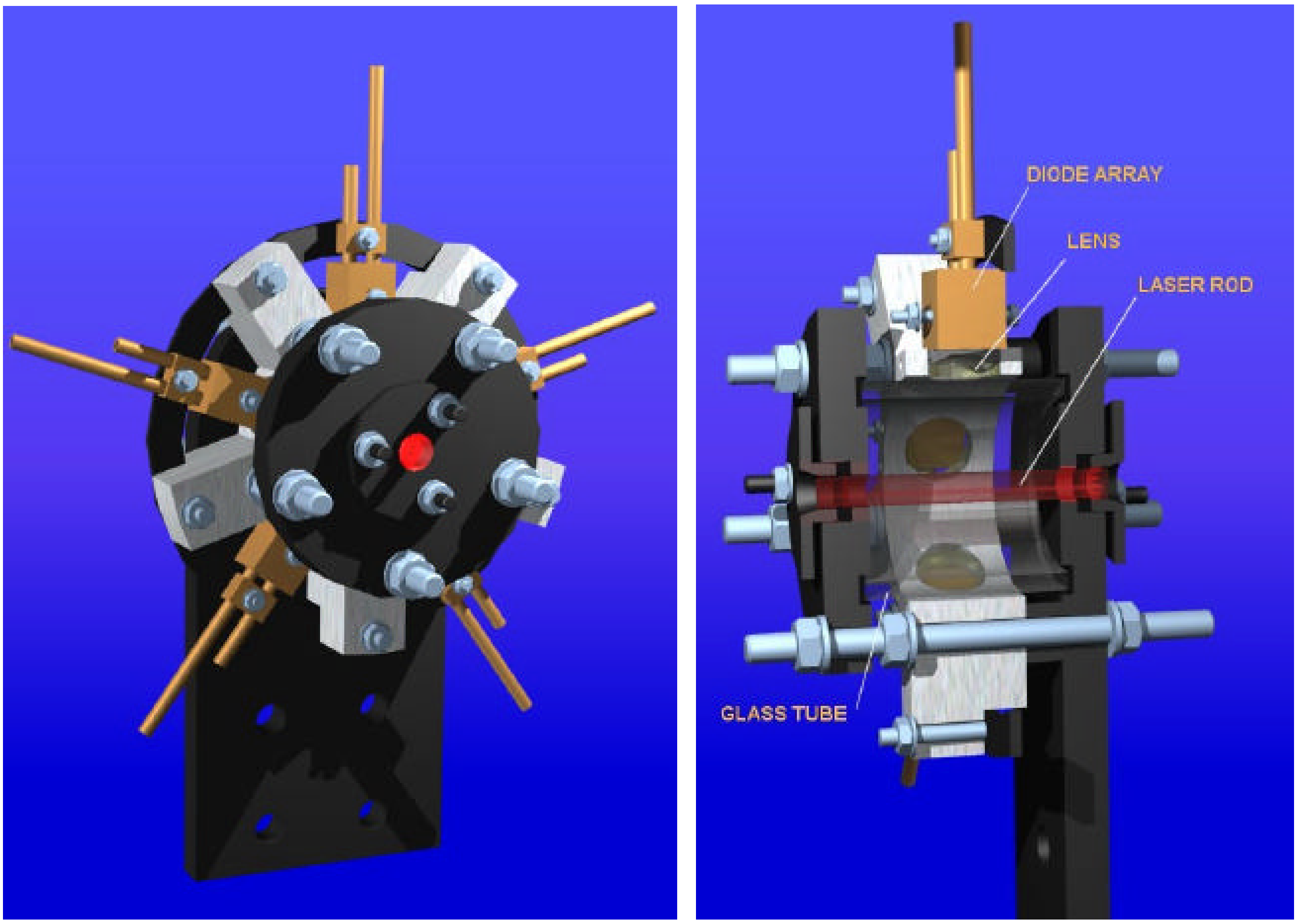
5kW DIODE-PUMPED TEST AMPLIFIER



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SUMMARY

? **Gain** - OK, suggest high pump efficiency

? **Efficient extraction** - OK, but more accurate data required

? **Self-stabilisation** - Yes, to a few % but not well matched to analysis
- improvement anticipated
- needs slow feedback system

? **30% amplified beam uniformity**
- better with fatter rod

? **Thermal lensing and astigmatism measured**
- predict good correction for CLIC power

? **Polished rod fractured at predicted power/cm**
- etched rod believed better

REMAINING CHALLENGES FOR CLIC?

*STABILITY
- Requires slow feedback system
- Fast feedback system??

*SYNCHRONISATION - To be determined

*UNIFORMITY
- OK improvements expected
- options possible

*AMPLIFIED PULSE TRAIN - Low risk

*ENERGY EXTRACTION OVER LARGE AREA
- Low risk

THE PHOTO-INJECTOR OPTION

***BACKGROUND**

***CLIC/CTF3 DESIGN STUDY**

***‘PILOT’ TESTS ON CTF2**

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DESIGN STUDY ISSUES

*PHOTO-CATHODE	robust, QE, stable
*DP OSCILLATOR	power, repetition rate
*DP AMPLIFIER	power, efficiency, stability
*HARMONIC GENERATION	efficiency
*FEEDBACK	0.1%?
*SYNCHRONISATION	1ps

OUTSTANDING ISSUES

***1.5GHz(CTF3)/0.5GHz(CLIC) oscillator**

***Electron charge measurement and stabilisation to 0.1%**

***Synchronisation**

***Photo-cathode reliability**

PHOTO-CATHODE ILLUMINATION

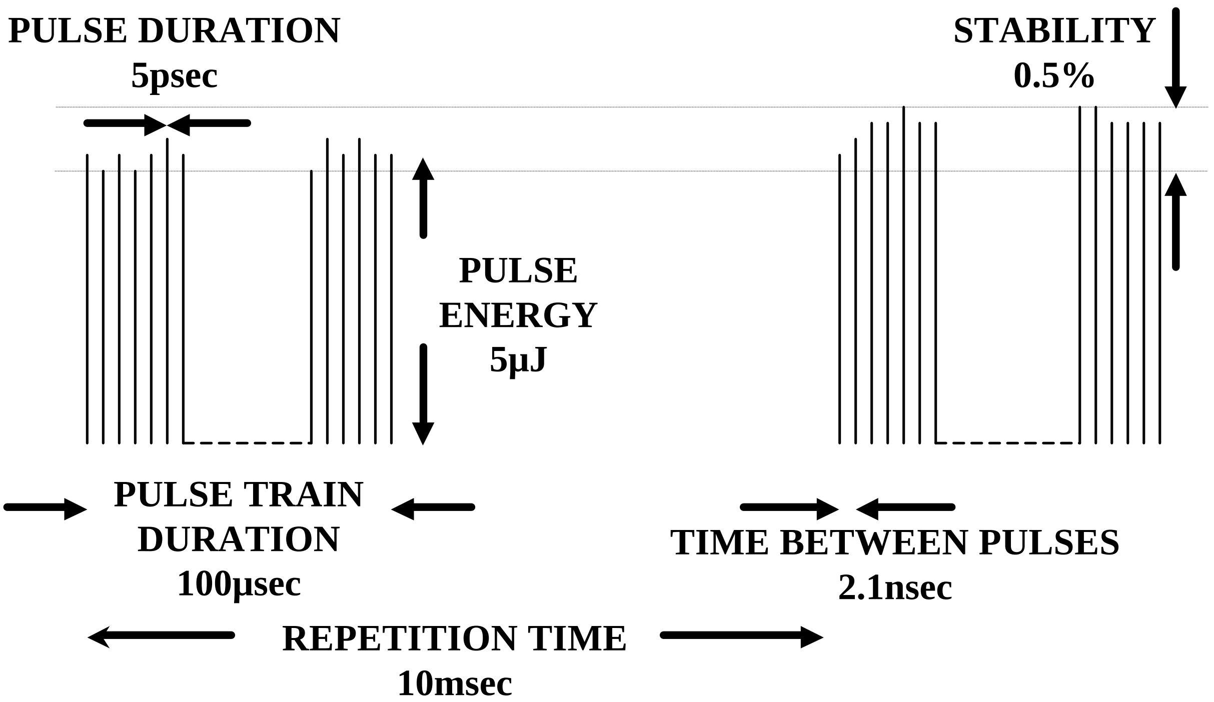


PHOTO-CATHODE SPECIFICATIONS

	CLIC	CTF3
UV energy per micropulse	5µJ	0.84µJ
Pulse duration	**‹10ps**	‹10ps
Wavelength	**‹270nm**	‹270nm
Time between pulses	**2.13ns**	**0.67ns**
Pulse train duration	91.6µs	1.4µs
Repetition Rate	100Hz	5Hz
Energy stability	**‹ 0.5%**	‹ 0.5%
Laser/RF synchronisation	**‹1ps**	‹1ps
Reliability	**10^9 shots between servicing 4 months at 100Hz**	

LASER SPECIFICATIONS

Energy per micropulse	**100µJ**
Total pulse train energy	**4.3J**
Pulse train mean power	**47kW**
Laser average power	**430W**
Shot to shot stability and controllability	**0.5%**

KEY ISSUES

- 0.5% Stability and Controllability
- 47kW pulse train power
- 430W average power
- 1ps synchronisation

State of the Art

Commercial Systems

10W cw TEM_{00}	Nd:Vanadate	- for pumping TiS (eg Millenia)
1kW cw	Nd:YAG	-for engineering applications
1J/100Hz	Nd:YAG	-for engineering applications

Demonstrated Systems

Oscillators-	5kW multimode
	200W cw TEM_{00}
	50W cw modelocked TEM_{00}
MOPA-	10J/100Hz
	10mJ / 15 fs/ 1kHz

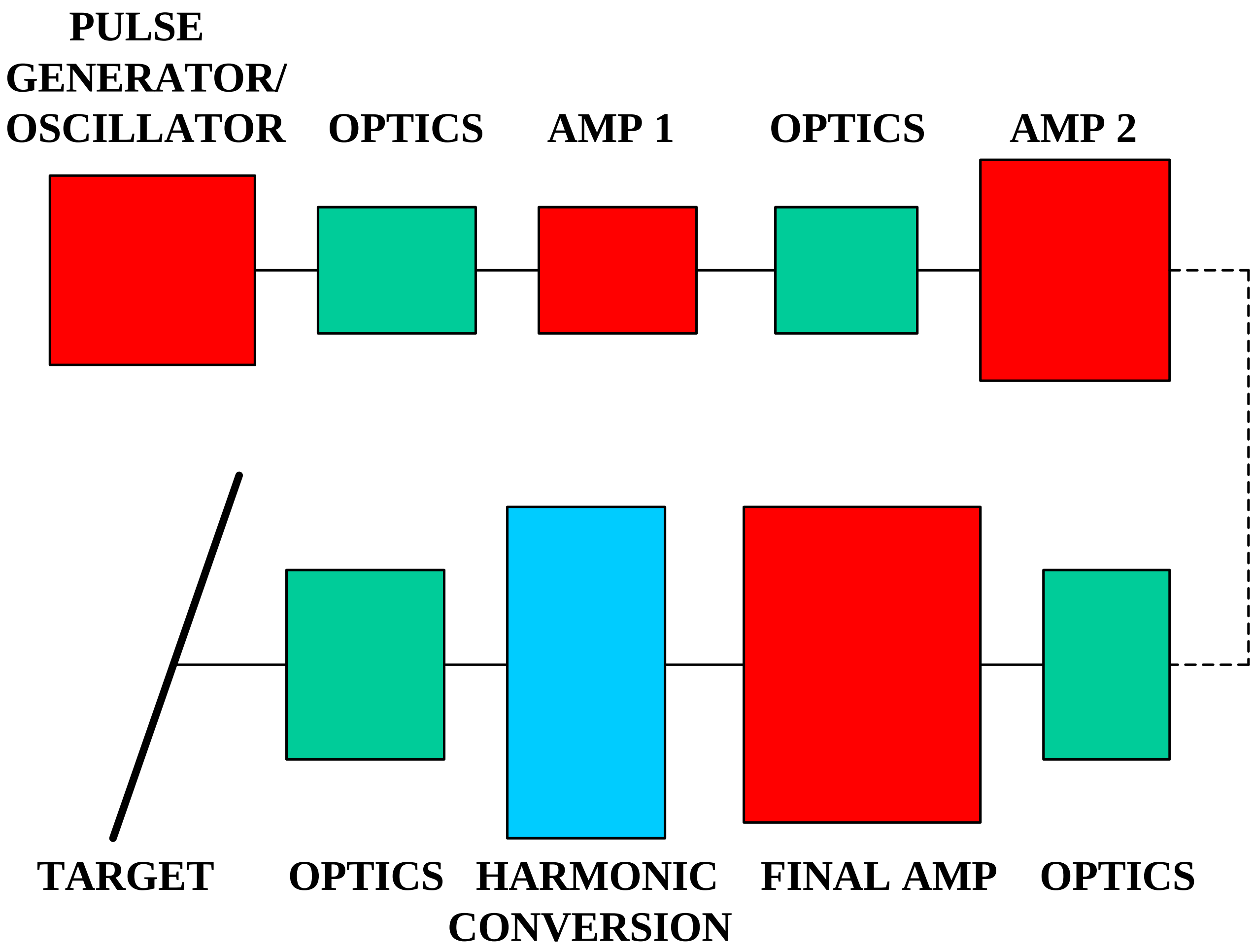
Designed Systems

Oscillators-	>10kW
MOPA -	>100kW

BASIC DESIGN STRATEGY

Stability	**- CW or QUASI-CW laser** **DIODE-PUMPING** **fast FEEDBACK** **fully SATURATE amplifiers**
Pulse train power **47kW**	**- min. diode pump power** **(min. COST)** **max. pump efficiency** **AMP. DESIGN/ MATERIAL** **max. extraction efficiency** **STAGING OPTICS**
Average power **420W**	**- thermal dynamics** **MATERIAL FRACTURE** **OPTICAL DISTORTION**
Simple design	**- small number of rod amplifiers** **with high gain - MATERIAL**
UV efficiency	**- important since gives min. COST** **OPTICS**

BASIC LASER SYSTEM



MATERIAL

Nd:YLF — **High efficiency**
High gain
Low distortion

cw MODELOCKED ND:YLF OSCILLATOR

Available commercially
Expected performance — **- 50W @ 0.5GHz (CLIC)**
- 5ps @ 1047nm

NUMBER OF AMPLIFIERS

Available input energy per pulse = 100nJ
Required output energy per pulse = 100µJ

Required amplifier gain = 1,000

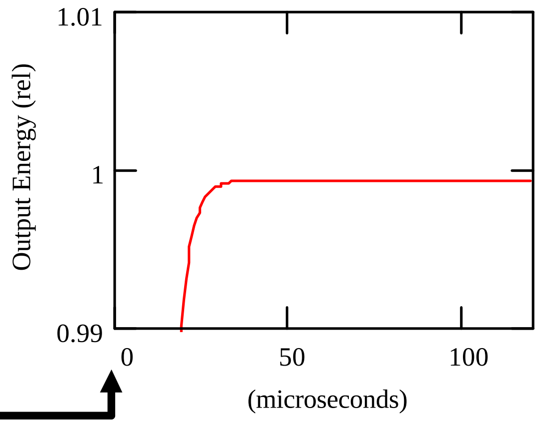
Simple system has 3 amplifiers with average gain per amplifier of 10.

FINAL AMPLIFIER DESIGN - PHYSICS

Requirements - diode pump power › output power (47kW)
- efficient extraction of diode power
- high stability along the pulse train

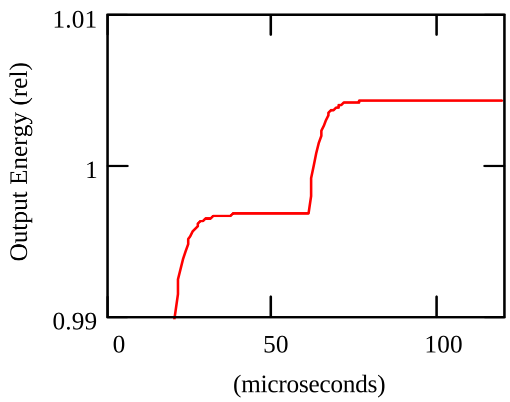
Simulations carried out for single and double pass amplifiers.

For maximum stability the trick is to operate in quasi-steady-state mode with continuous pulse train input.

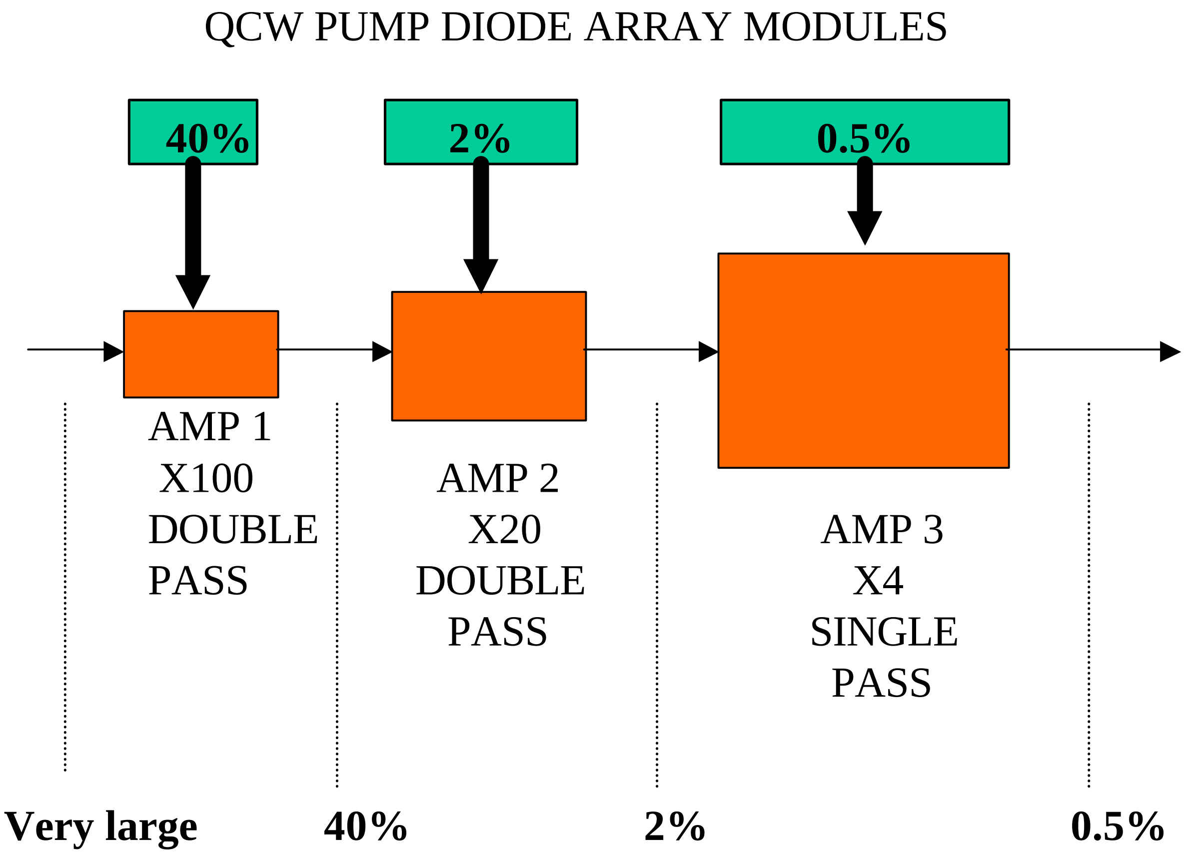


Start of diode pump

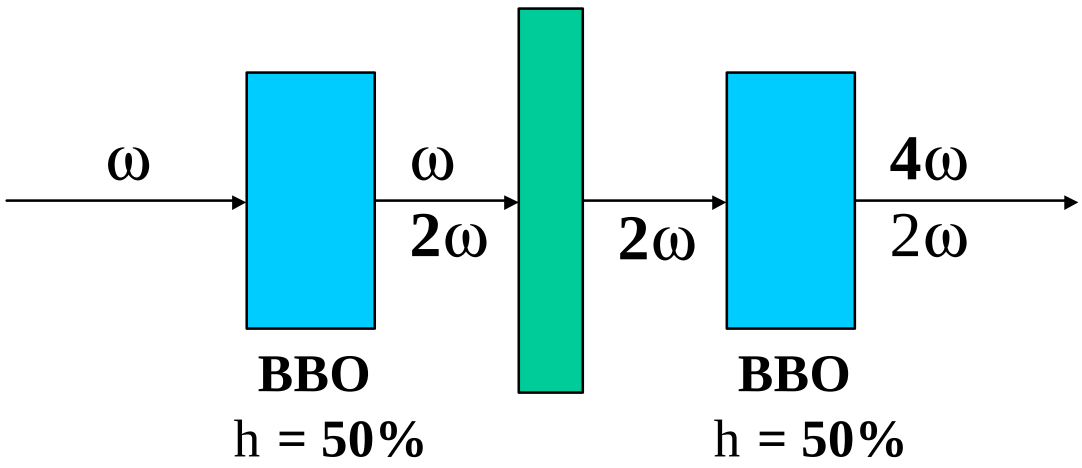
Sensitivity to 1% changes in input energy and pump power



AMPLIFICATION SCHEME
TOLERANCES FOR 0.5% STABILITY



FOURTH HARMONIC GENERATION



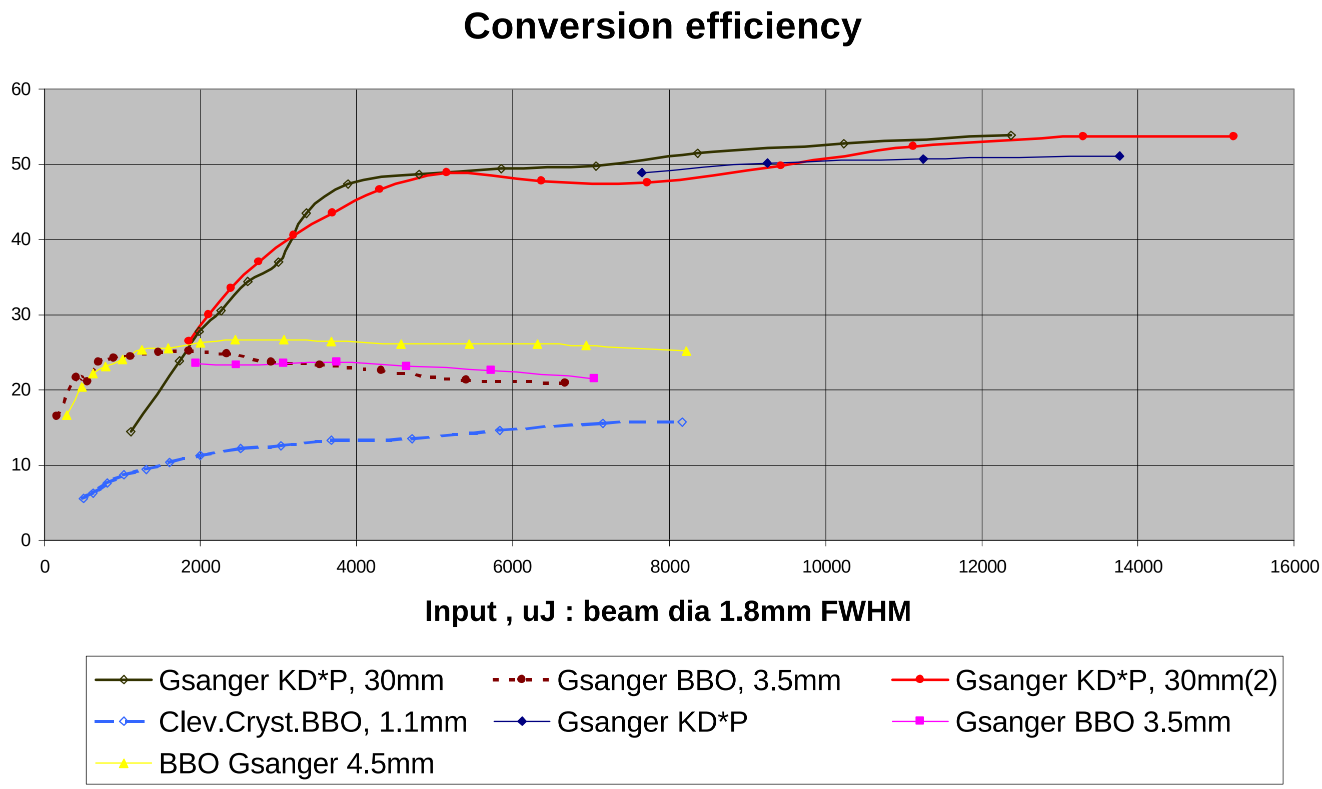
•Predicts 25% efficiency overall

•Literature reports 25% efficiency

•Requires optics to give square flat-top beam

•Design assumed 10% - achievement of say 20% would substantially cut the cost of laser.

SECOND AND FOURTH HARMONIC CONVERSION EFFICIENCY MEASUREMENTS



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OPTICS DESIGN

REQUIREMENTS

- **Stability requires generation of a single mode beam.**
- **For maximum efficiency the beam must have a square flat top profile at**
  - **amplifiers**
  - **harmonic crystals**
  - **photo-cathode**
- **Compensation for thermal lensing in amplifiers.**

DEVELOPMENT PROGRAMME

- **Photo-cathode performance - encouraging results**

- **High power cw mode-locked Nd:YLF oscillator**
  operation at 0.5GHz

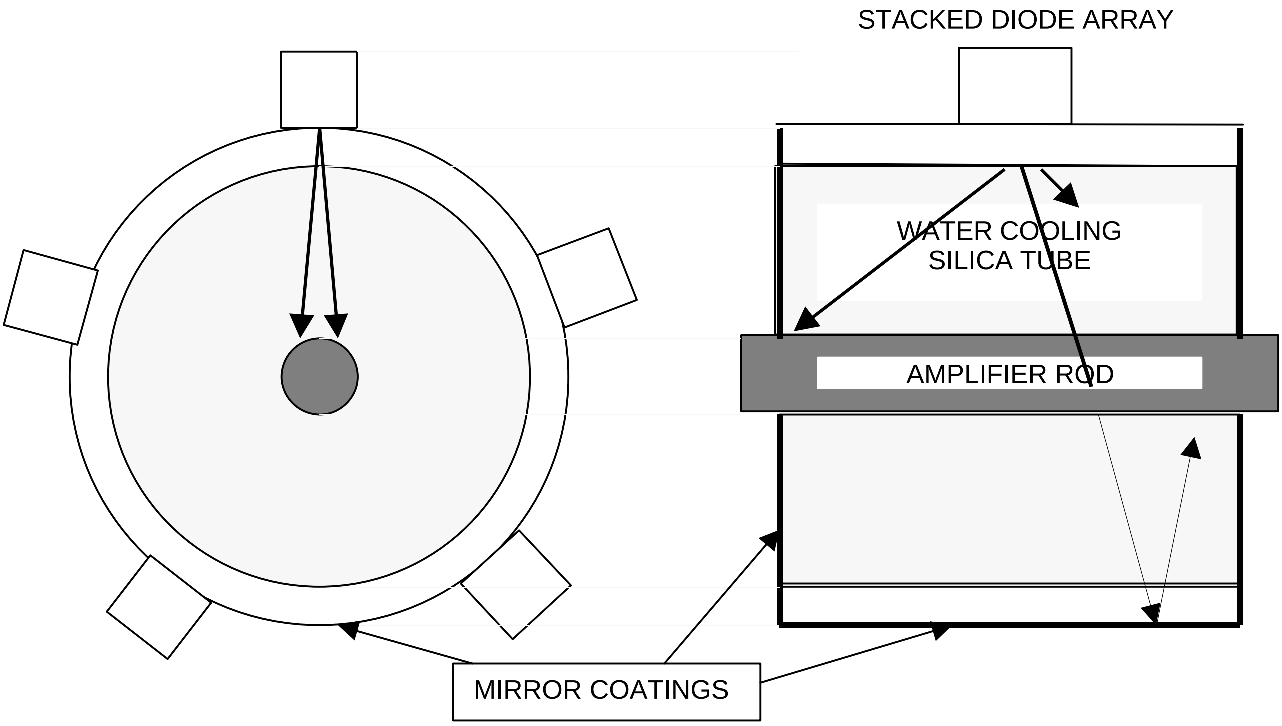
- **Feedback control of a) laser pump diode current (μsec)**
  b) fast optical gate (nsec)
  needs FAST ACCURATE (0.1%) monitor

- **Amplification - highly stabilised output pulse train**
  - high efficiency
  - lensing compensation

- **Fourth harmonic generation - high efficiency**

- **Check laser damage thresholds**

TEST AMPLIFIER DESIGN - LAYOUT



•Scaled down diameter (5mm rod)

•Reduced stacked array length (5kW total)

•Measure efficiency
stability
under conditions of heavy saturation

CONCLUSIONS

•FEASIBLE

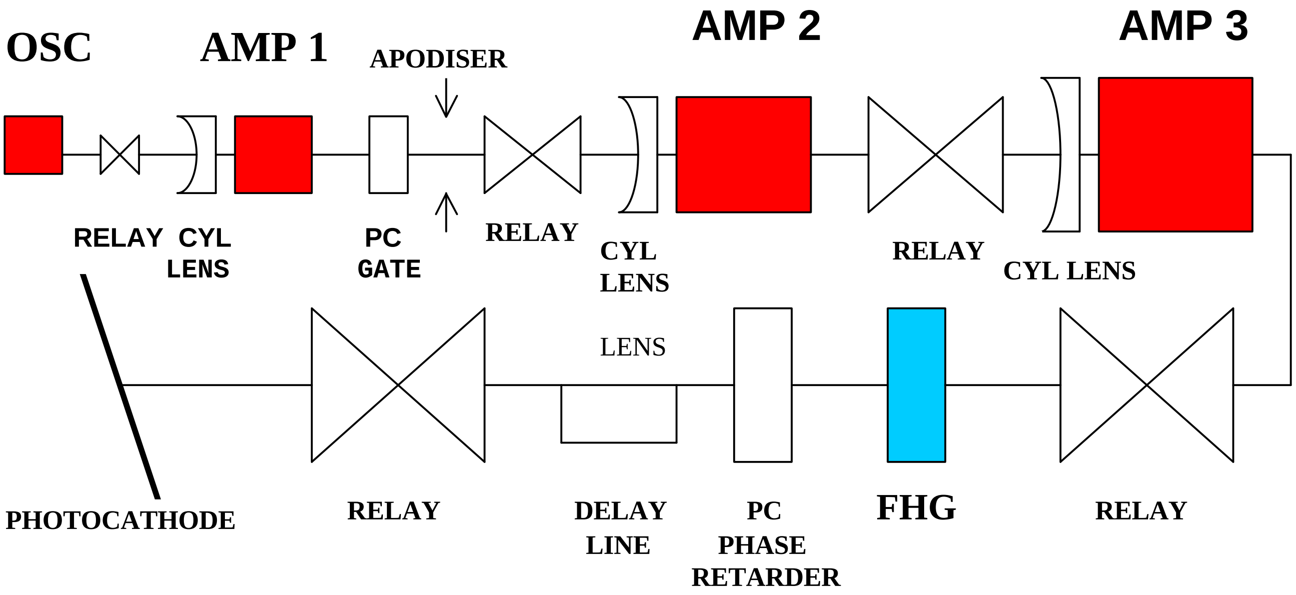
•AFFORDABLE

Total pump power for CLIC ~75kW
@ $7/W gives $0.5M for the diode arrays
and a system cost of perhaps $1M

•INITIAL TESTS indicate good efficiency and stability

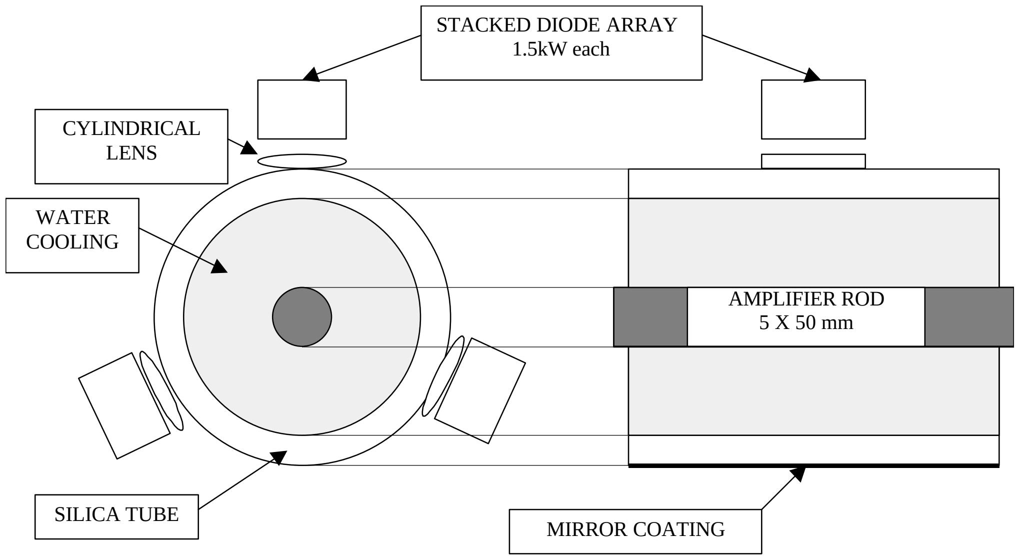
•BASIS for other laser-particle beam applications

OPTICS SCHEME FOR PHOTO-INJECTOR LASER SYSTEM



PROPOSED RAL PROGRAMME

Amplifier development - test as close to design parameters as possible
- at minimum cost



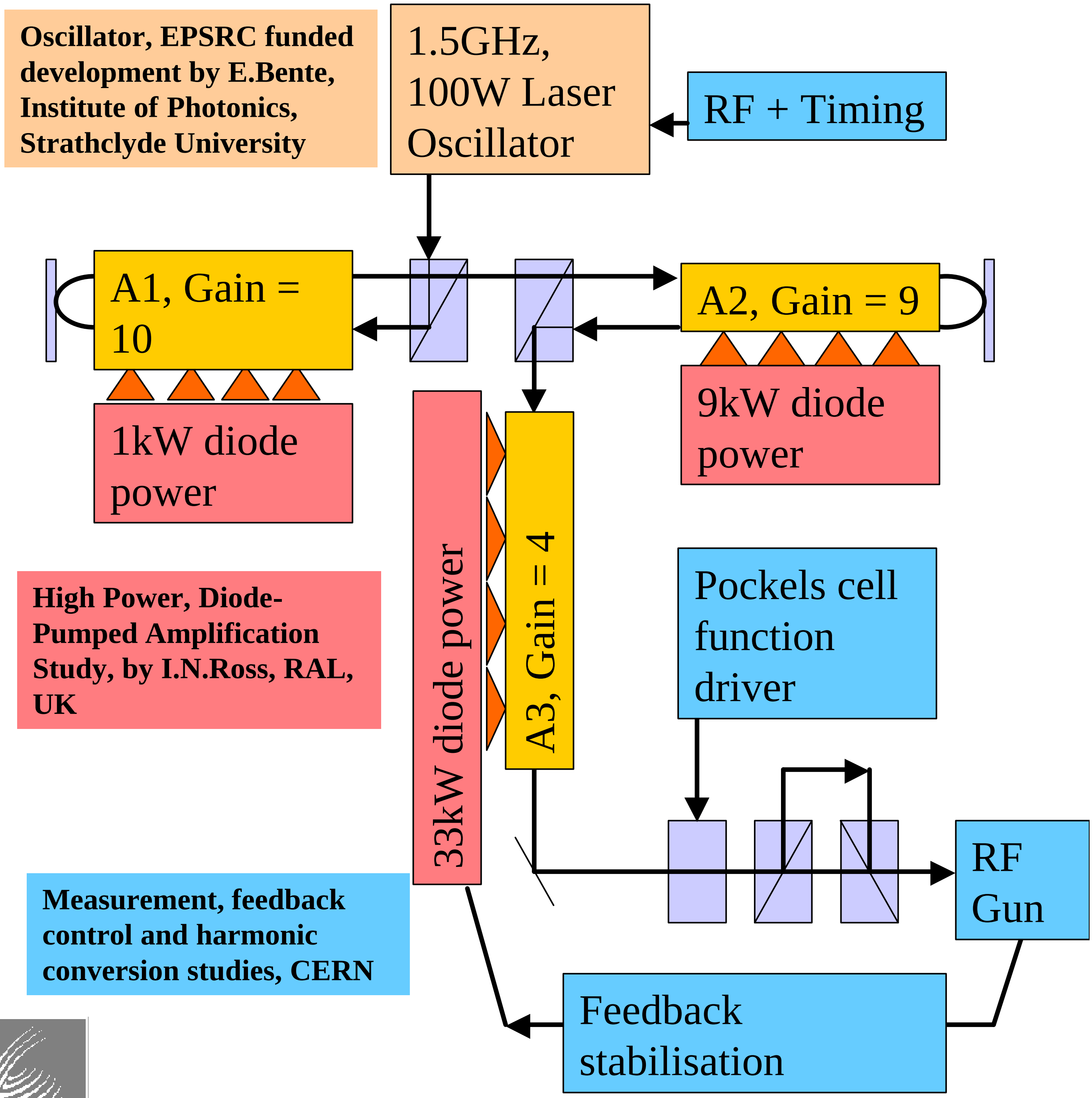
Scaled down version with short length - 4.5kW pump
Gives measurable small signal and saturated gain

Good test of:
- pump efficiency
- gain
- steady state saturated operation
- extraction of stored energy
- thermal effects

Develop theory and simulations

THE CTF3 PHOTO-INJECTOR LASER SYSTEM

RAL, Strathclyde University and CERN



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‘PILOT’ CTF2 TESTS

AIMS

Demonstrate stable pulse train operation yielding 0.2nC per electron bunch from the photo-cathode at a frequency of 250MHz and for a train length of 1.5µs.

Demonstrate optical feedback stabilisation of the optical pulse train to 1%.

Demonstrate beams on the photo-cathode spatially uniform to 30%.

PHOTO-INJECTOR LASER FOR ‘PILOT’ TESTS