N90-21804

SOLAR-PUMPED LASER FOR FREE SPACE POWER TRANSMISSION

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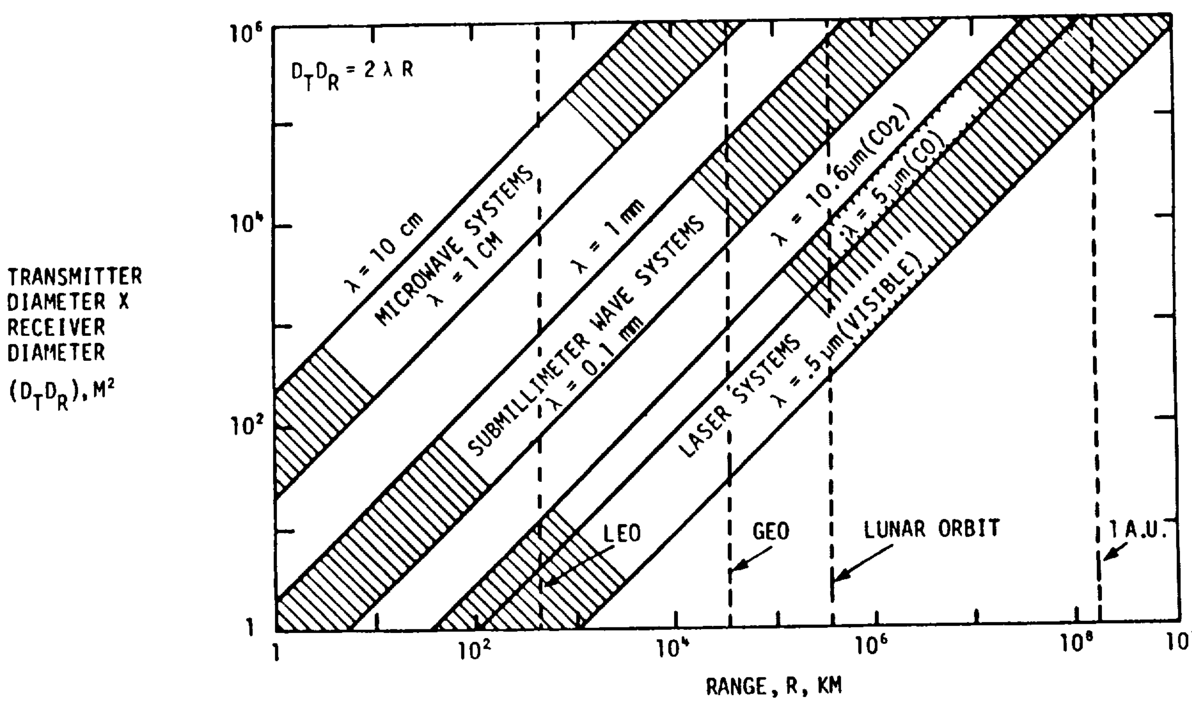
LASER POWER TRANSMISSION

- LASER IS ONLY FEASIBLE SYSTEM FOR LONG RANGE (> $1{,}000_{KM}$) POWER TRANSMISSION IN SPACE.
- LASER BEAM ACTS AS "SUPER CONDUCTOR" TO DELIVER HIGH GRADE POWER--NEAR ZERO ENTROPY.
- MULTIMISSION SUPPORT POSSIBLE--ECONOMICAL.
- LIGHT WEIGHT SYSTEMS IDENTIFIED-DIRECT SOLAR PUMPED LASERS AND LASER DIODE ARRAYS.

TRANSMITTER/RECEIVER SIZES vs RANGE



LASERS AVAILABLE FOR LASER POWER TRANSMISSION

O REQUIREMENTS

LASER POWER	> 10 MW	ORBITAL MANEUVERING
	> 1 GW	EARTH-TO-ORBIT LAUNCHING (> 1 TON)
	~ 1 MW	OTHER MISSIONS
PHOTON FLUX	< 2×10^5 W/cm^2	CW
	< 2×10^7 W/cm^2	PULSED (LSD PROP.)
WAVELENGTH	> 10 μm	THROUGH ATMOSPHERE
	~ 1 μm	DEPENDS ON THE POWER RECEIVERS IN FREE SPACE
PULSE WIDTH	50 ns - 1 μs	PLASMA GEN. AND HEATING
EFFICIENCY	HIGH	TRANSMITTER AND RECEIVER

O GROUND BASED WITH SPACE RELAY

FREE ELECTRON LASER (PULSED), CO_2 LASER (CW)

STATE-OF-THE-ARTS: MULTI-KILOWATT (CW), 500 kJ (PULSED)

SCALING-UP: POSSIBLE TO MULTI-MW LEVEL.

O TECHNICAL ISSUES:

MANY ORDERS OF MAGNITUDE UP-SCALING NEEDED

ATMOSPHERIC INTERFERENCE

SPACEBORNE LASER OPTION SHOULD BE CONSIDERED

SPACE-BORNE LASERS FOR POWER TRANSMISSION

O SOLAR POWERED LASERS

DIRECT SOLAR PUMPED LASERS

IODINE PHOTODISSOCIATION LASER, IBr PHOTODISSOCIATION LASER

SOLID STATE LASERS (Nd^{3+}), LIQUID Nd^{3+} LASERS, DYE LASERS

INDIRECT SOLAR PUMPED LASERS

N_2-CO_2 BLACKBODY PUMPED LASER, CO BLACKBODY PUMPED LASER

SOLAR PHOTOVOLTAIC POWERED

ELECTRIC DISCHARGE LASERS (EXCIMER, COPPER, CO_2)

DIODE LASER ARRAYS/DIODE LASER PUMPED LASERS.

O NUCLEAR POWERED LASERS

DIRECT NUCLEAR-PUMPED LASERS

HIGH EFFICIENCY ELECTRIC DISCHARGE LASERS OR DIODE LASERS

SOLAR PHOTOVOLTAIC ELECTRICALLY PUMPED ONE MW LASER SYSTEMS

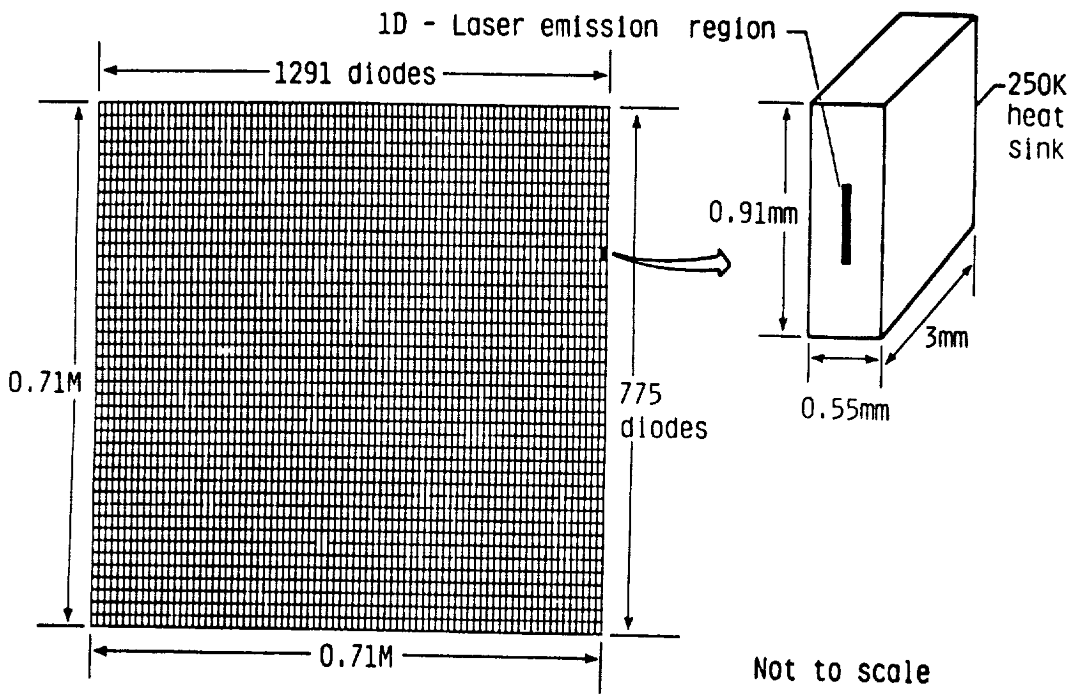
		KrF EXCIMER	COPPER VAPOR	DIODE ARRAY	CO_2	REMARKS
LASER WAVELENGTH	µM	0.248	0.510 0.570	0.8	10.6	
INTRINSIC EFFICIENCY	%	10	3	30	13.7	
ELECTRIC EFFICIENCY	%	2.5	1.4	30	5.5	WALL-PLUG EFF.
SOLAR TO LASER EFFICIENCY	%	0.40	0.24	6.0	0.88	
SOLAR POWER COLLECTED	MW	250	412	16.5	113.5	
ELECTRIC POWER FROM PV ARRAY	MW_E	50	82	3.3	22.7	20 PERCENT EFFICIENCY
SOLAR PANEL AREA	M^2	185,185	305,185	12,318	84,444	$1.35 KW/M^2$ AMO
THERMAL RADIATED POWER	MW	49	81	2.3	21.7	OTHER THAN SOLAR ARRAY
RADIATOR TEMP./AREA	$K/1000M^2$	300/21.8 373/27.3 326/14.1	300/107 1770/.057	250/10.4 ——	300/9.8 409/10.8	
	TOTAL	63.2	107.057	10.4	20.6	

SOLAR PHOTOVOLTAIC PUMPED ONE MW LASER SYSTEMS

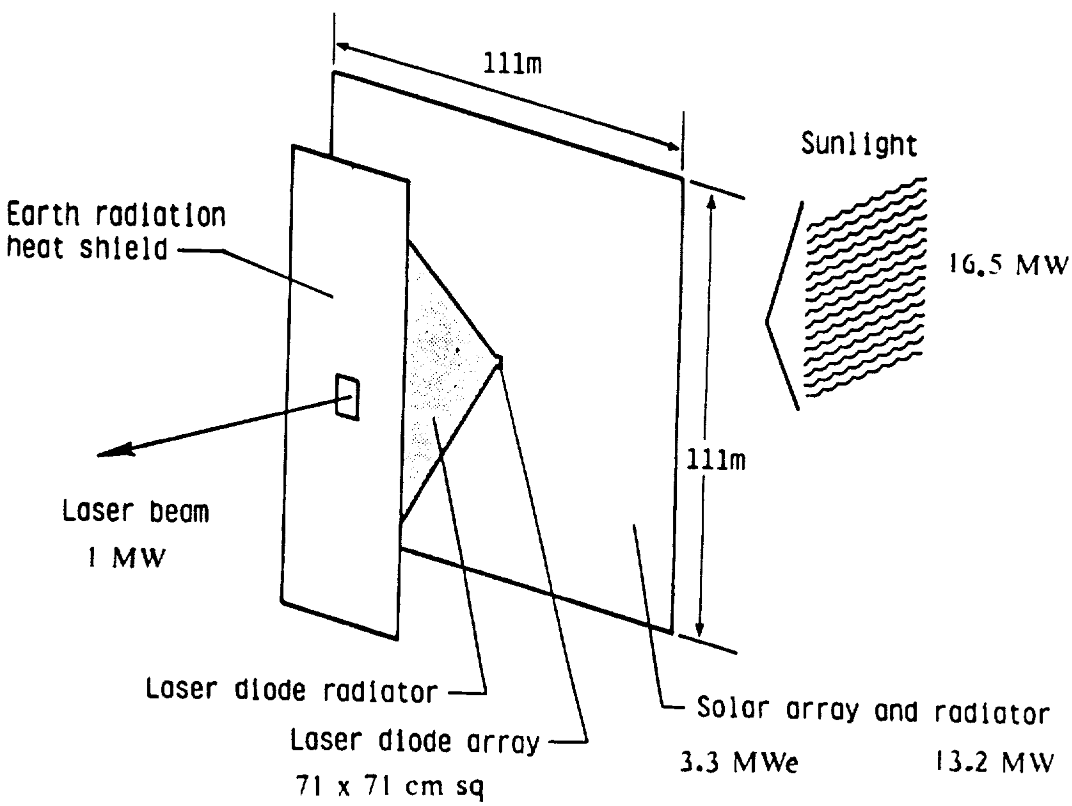
		KrF EXCIMER	COPPER VAPOR	DIODE ARRAY	CO_2	REMARKS
ELECTRIC EFFICIENCY	%	2.5	1.4	30	5.5	AFTER POWER CONDITIONING
ELECTRIC POWER	MWE	50	82	3.3	22.7	
SOLAR PANEL AREA, MASS	M^2 KG	185,185 166,666	305,185 273,333	12,318 11,000	84,444 76,000	20% EFFICIENCY 300 W/KG (REF. 1)
POWER CONDITIONER	KG	88,000	144,320	5,808	40,120	1.76 KG/KWE (REF. 2)
THERMAL POWER	MW	49	81	2.3	21.7	
RADIATED						
RADIATOR AREA MASS	M^2 KG	63,200 170,640	107,057 289,054	10,400 28,080	20,600 55,620	$2.7 KG/M^2$ (REF. 3)
TOTAL MASS	KG	425,306	706,707	44,888	171,740	LASER CAVITY MASS NOT INCLUDED

REF. 1 - E. A. GABRIS AND A. D. SCHNYER, PROC. 22ND IECEC AUG 1987, P. 33
2 - J. A. MARTIN AND L. WEBB, PROC. 22ND IECEC AUG 1987, P. 321
3 - E. P. FRENCH, 15TH IECEC, 1980, P. 394.

2D LASER DIODE ARRAY



1MW LASER DIODE ARRAY SYSTEM



LASER DIODE ARRAY TECHNICAL ISSUES

ADVANTAGES:

- O HIGH SYSTEM EFFICIENCY (6%)
- O SMALL AND POTENTIALLY LEAST MASSIVE SYSTEM
- O NO LASANT FLOW REQUIRED
- O REASONABLE LASER WAVELENGTH
- O LASER DIODE ARRAY HAS GOOD POWER COUPLING TO SOLAR ARRAY
- O LOW WEIGHT/SIZE WASTE HEAT RADIATOR

DISADVANTAGES:

- O LOW TEMPERATURE LASER OPERATION REQUIRES LOW T RADIATOR AND HEAT REMOVAL SUBSYSTEM
- O VERY TEMPERATURE SENSITIVE
- O EFFECTS OF SPACE RADIATION MAY BE SEVERE

TECHNICAL ISSUES:

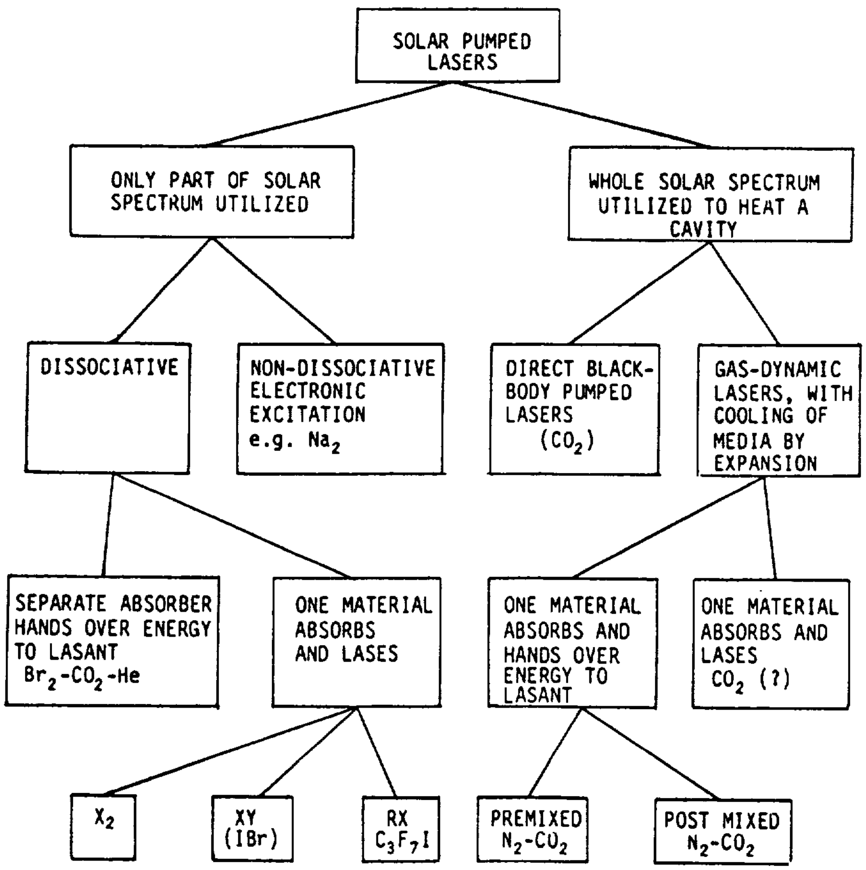
- O PHASE MATCHING ENTIRE LASER ARRAY NOT DEMONSTRATED
- O SCALING PRESENT 1-WATT SINGLE DIODES TO 1MW DIODE ARRAY
- O ARRAY COOLING WITH HEAT PIPES
- O ELECTRICAL DIODE LASER NETWORK

WEIGHT ESTIMATE OF DIODE PUMPED Nd YAG LASER SYSTEM

DIODE LASER EFFICIENCY		= 30%
PUMPING EFFICIENCY		= ND:YAG LASER OUTPUT/DIODE LASER INPUT
		= 35% (REF.)
ELECTRIC EFFICIENCY		= 10.5%
SOLAR DIODE LASER EFFICIENCY		= 6%
OVERALL SYSTEM EFFICIENCY		= .06 X .35 = .021 OR 2.1%
SOLAR POWER COLLECTED		= 1-MW/.021 = 48 MW
ELECTRIC POWER		= 48 MW X .20 = 9.6 MWE
		6.72 (THERMAL) + 2.88 MW (LASER)
SOLAR PANEL	AREA	35,477 M^2
	WEIGHT	32,000 KG 300 WR/RG
POWER CONDITIONING		16,896 KG 1.76 KG/KWE
COOLING POWER		8.6 MW
RADIATOR TEMPERATURE		300 K/350 K
	AREA	18,770 M^2
	WEIGHT	50,680 KG 2.7 KG/M^2
TOTAL WEIGHT		99,576 KG

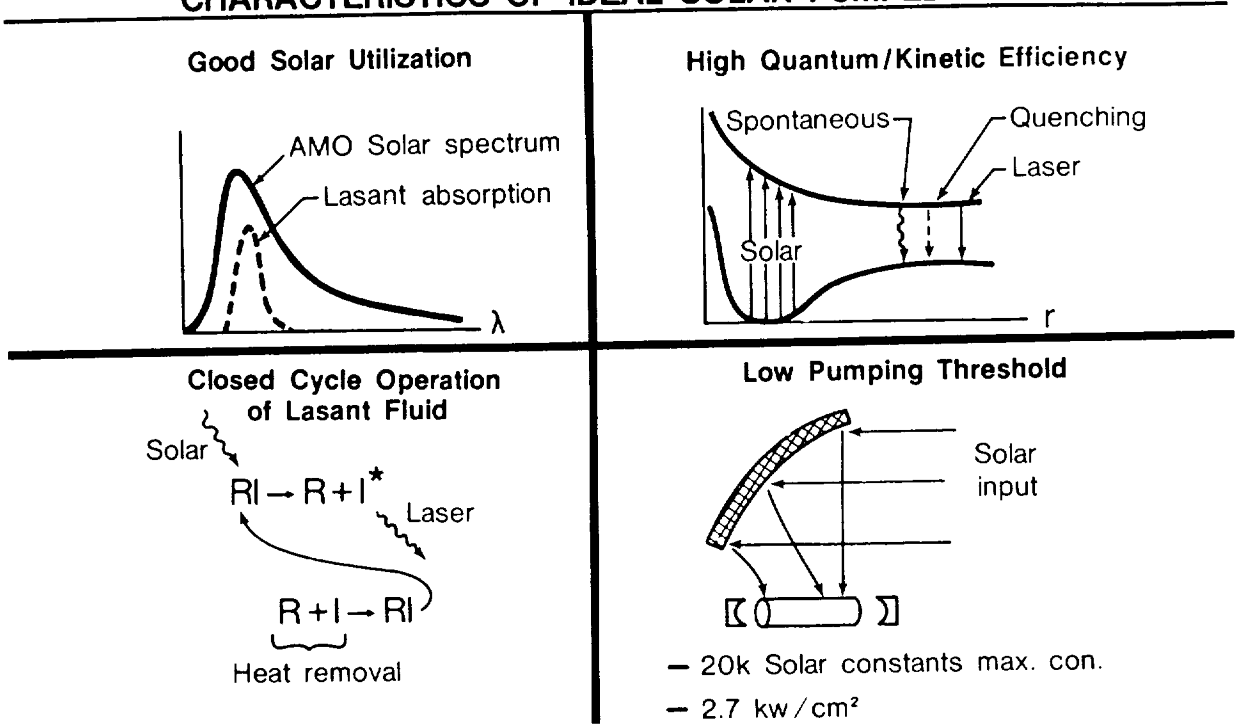
COMPARE: 44,888 KG FOR DIODE LASER ARRAY AND 30,270 KG FOR SOLAR IODINE LASER

VARIOUS SOLAR PUMPED GAS LASERS

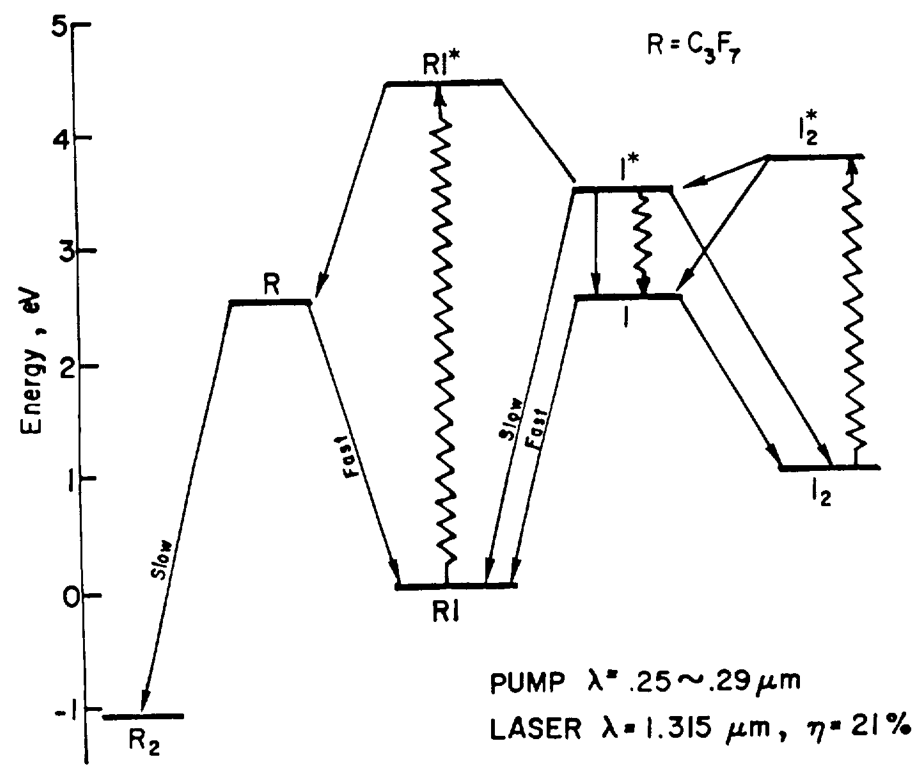


X = halogen, Y = different halogen atom
R = complex radical

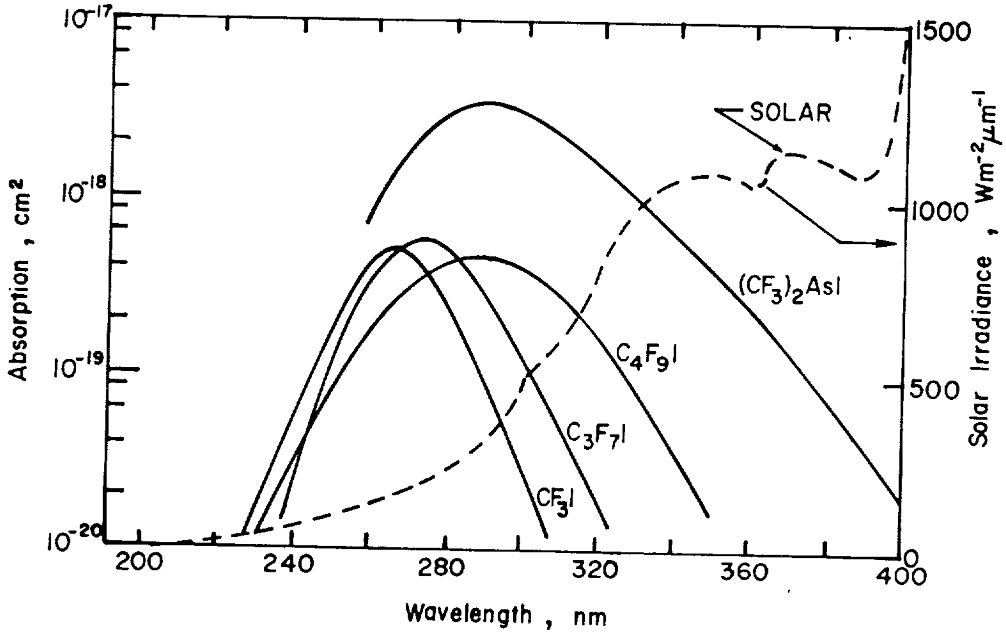
CHARACTERISTICS OF IDEAL SOLAR PUMPED LASER



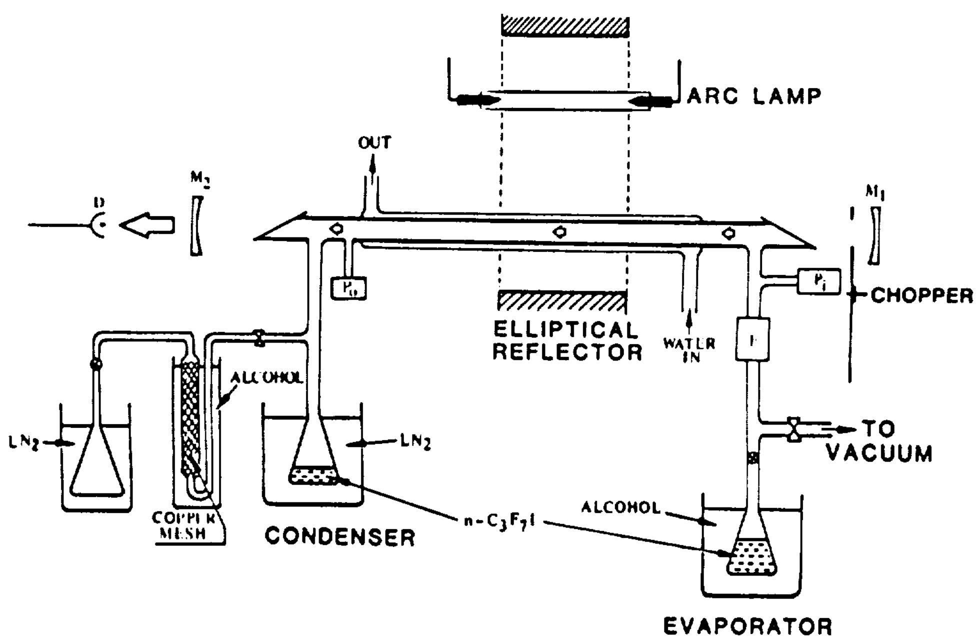
IODINE LASER KINETICS



ABSORPTION CROSS SECTIONS OF PERFLUOROALKYL IODIDES



SOLAR-PUMPED LASER EXPERIMENT



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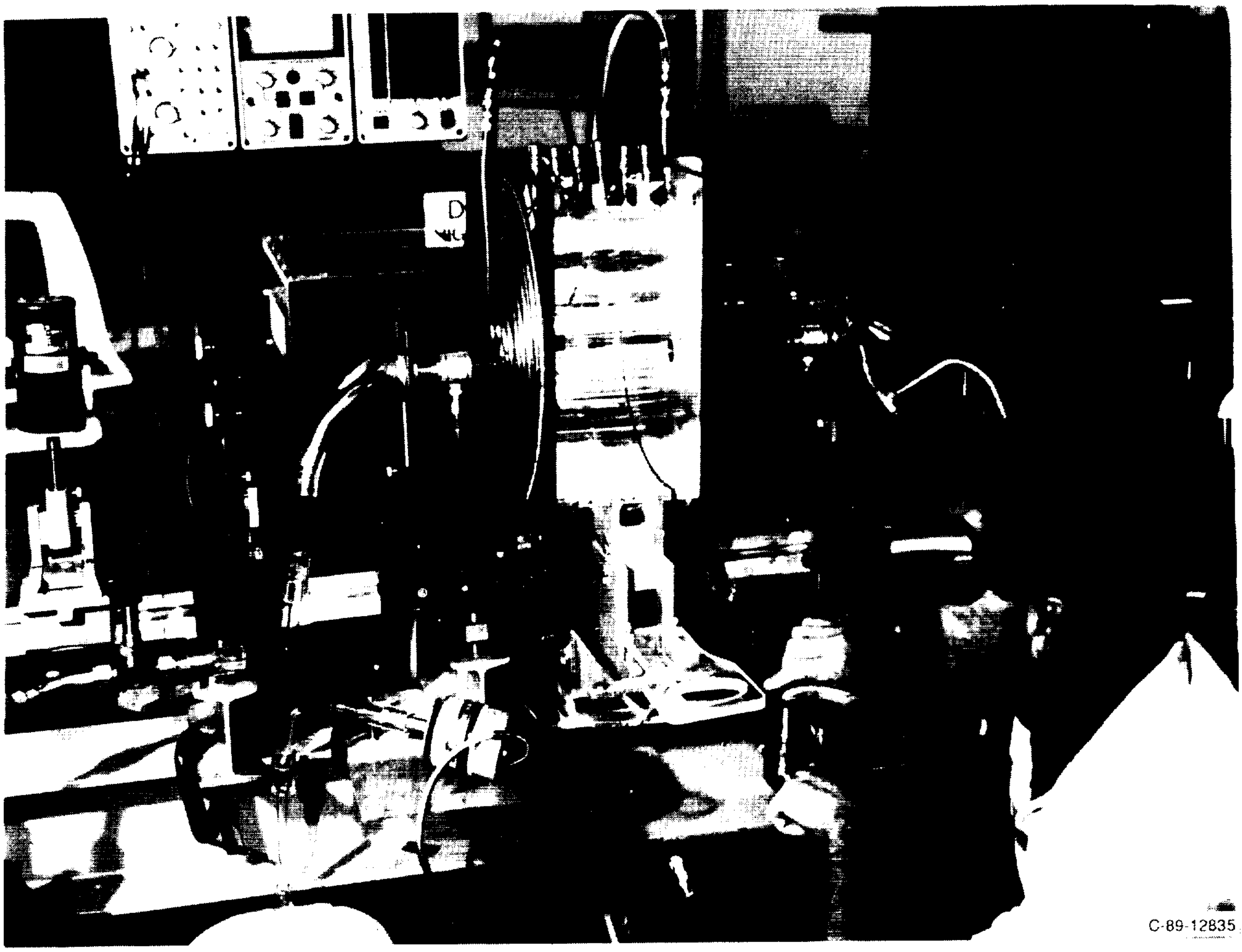
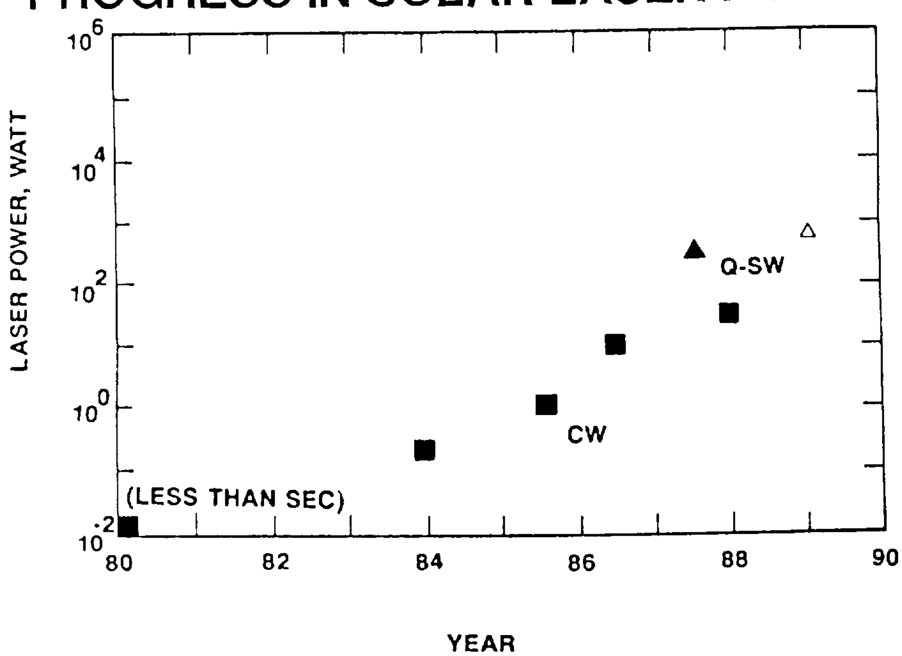
SOLAR SIMULATOR PUMPED IODINE LASER EXPERIMENT



PROGRESS IN SOLAR LASER POWER



STATUS OF SOLAR-PUMPED IODINE LASER

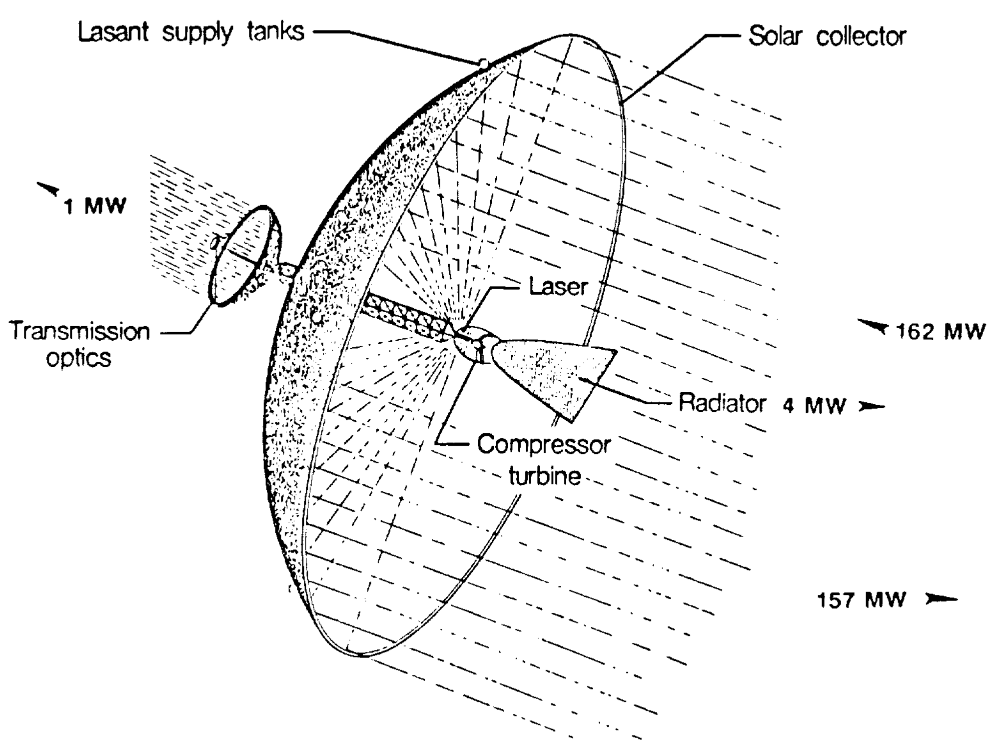
O KINETICS:	LASER MEDIUM	C_3F_7I, C_4F_9I
	99 PERCENT RECYCLABLE	
	PUMP BAND	250-290 NM NUV
	INTRINSIC EFFICIENCY	21 PERCENT
	EXCITATION MODE	PHOTODISSOCIATION TO I^*
	SOLAR-TO-LASER EFFICIENCY	0.2 TO 0.6 PERCENT

O SCALABILITY: PULSED POWER > 2 TW/2 KJ ACHIEVED (MARX-PLANCK INT.)
CW > 15 W ACHIEVED (WITH SOLAR SIMULATOR)
SCALING NO THEORETICAL LIMIT, 1 GW LEVEL POSSIBLE
1MW SYSTEM STUDY COMPLETED

O SOLAR-SIMULATOR PUMPED LASER EXPERIMENT:
15 W CW, > 250 W PULSED (Q-SWITCHED)
FLOW, SUBSONIC
REP. PULSED MOPA UNDER DEVELOPMENT

O R & D ISSUES: LARGE SOLAR UV COLLECTOR
CHEMICAL REVERSIBILITY
BEAM PROFILE CONTROL
FLIGHT EXPERIMENT FOR THERMAL MANAGEMENT/BEAM TRANSMISSION

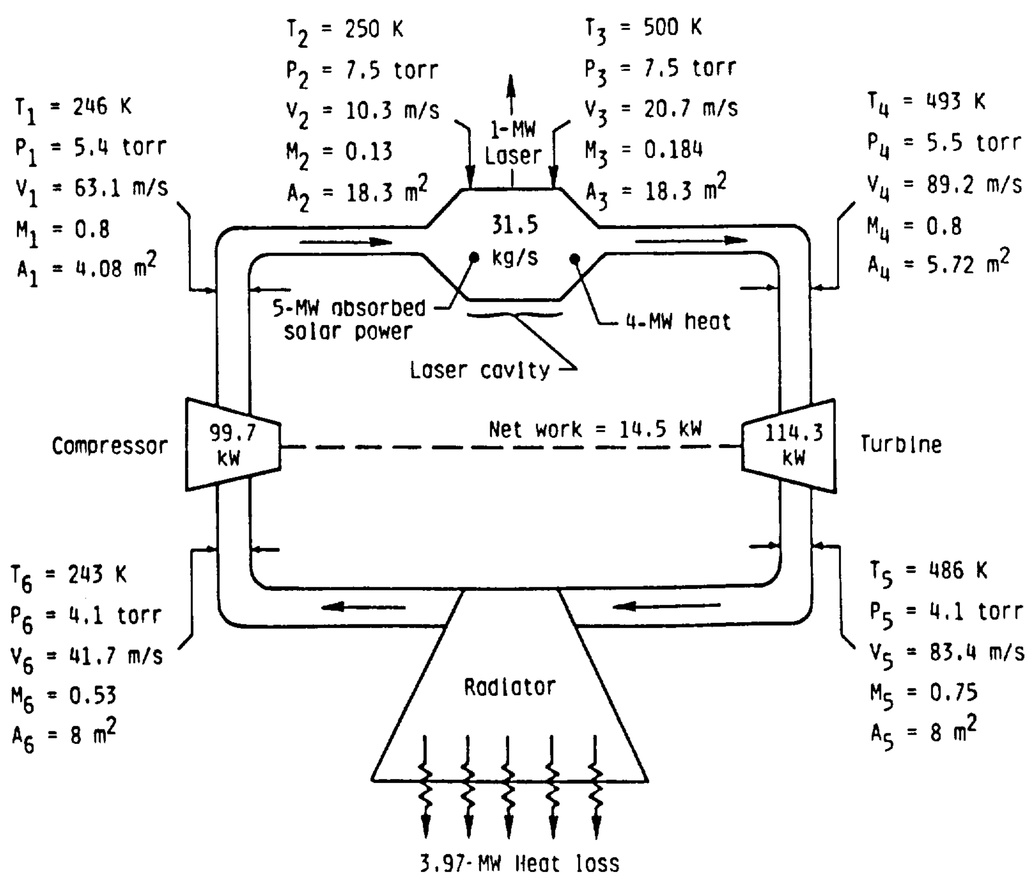
ONE MEGAWATT IODINE SOLAR PUMPED LASER POWER STATION



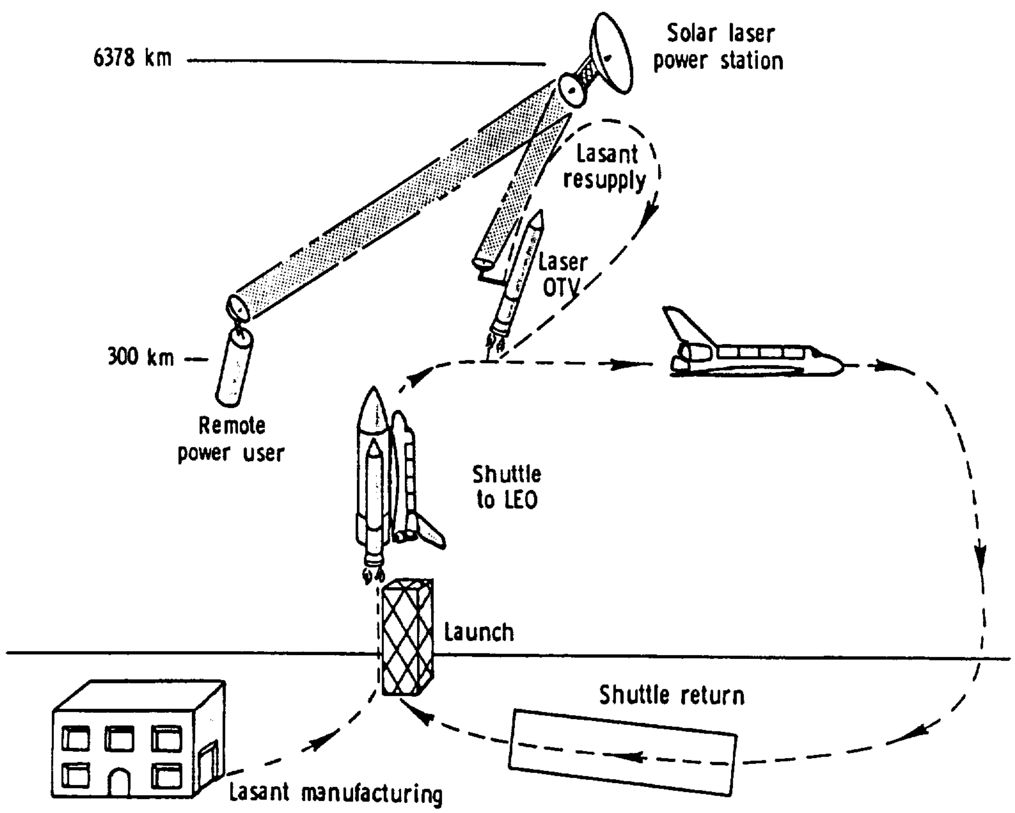
ONE MW SOLAR IODINE LASER SYSTEM MASS

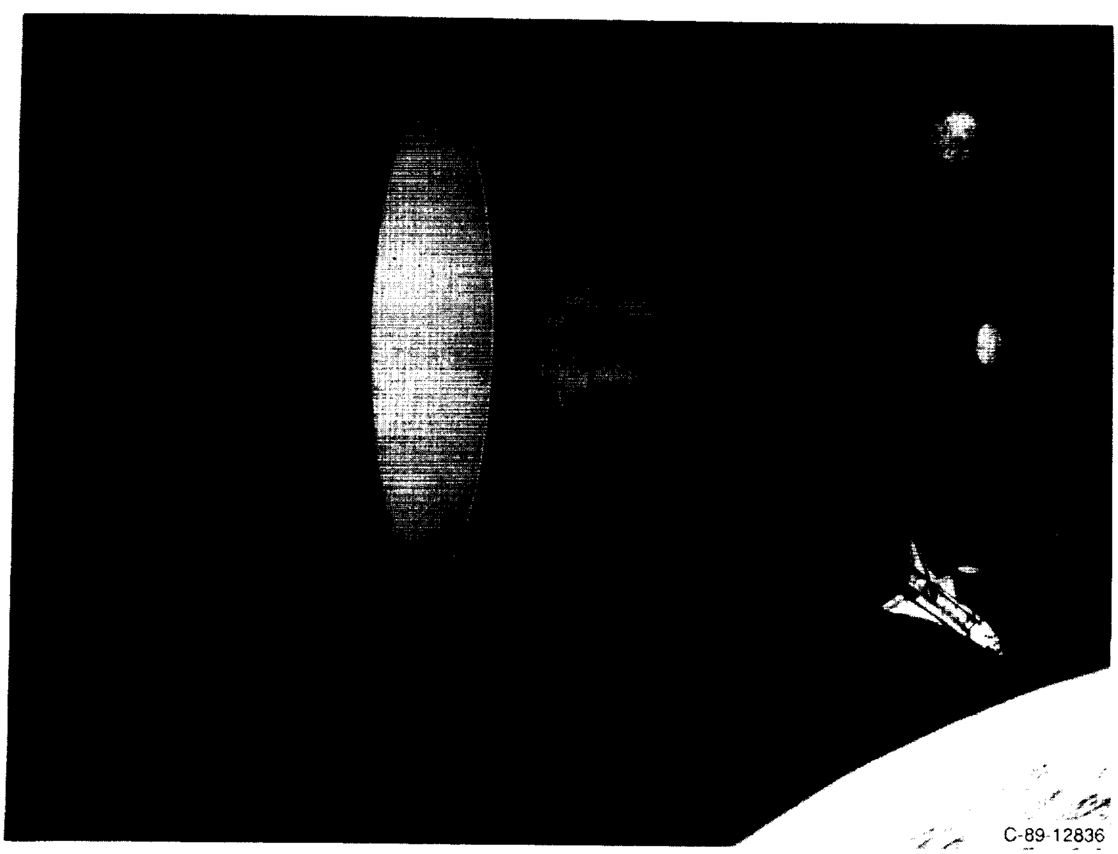
COLLECTOR, KG	14,800
RADIATOR, KG	15,470
TOTAL MASS FOR COLLECTOR AND RADIATOR, KG	30,270
OTHER SUBSYSTEMS:	
LASER CAVITY	
QUARTZ TUBE, KG	1,860
LASER CAVITY OPTICS, KG	1,000
LASER TRANSMISSION OPTICS AND STRUCTURE (27.6 M DIAM.), KG	24,000
GAS FLOW SYSTEM	
COMPRESSOR (2 STAGE), KG	12,700
TURBINE, KG	12,200
DUCTS, KG	3,000
T-C_4F_9I STORAGE TANKS (4 EMPTY TANKS), KG	270
ATTITUDE CONTROL SYSTEM (CMG AND FUEL)	
CMG, KG	2,000
150 KG FUEL/YR, KG	4,500

FLOW AND THERMAL CYCLES OF ONE MW IODINE LASER



OPERATION OF SOLAR PUMPED LASER POWER STATION





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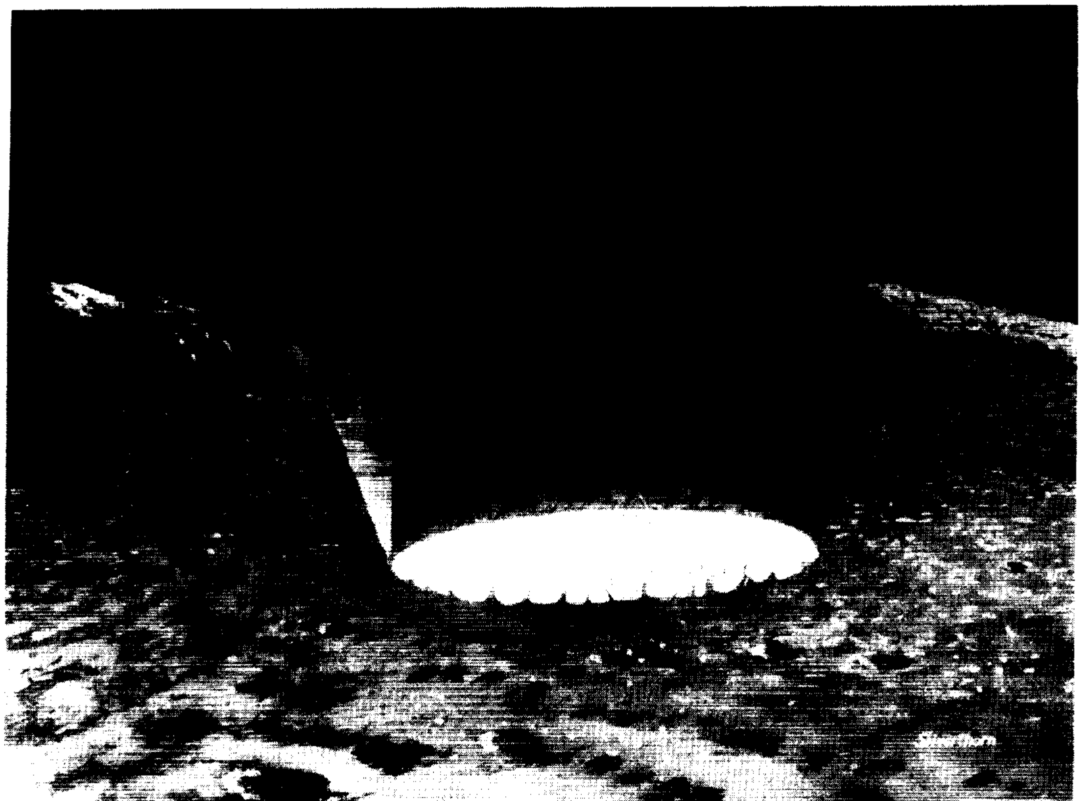
LASER POWER CONVERSION SYSTEMS

SYSTEM	EFFICIENCY
RECEIVER/PHOTOVOLTAIC/BATTERIES	34.0 %
RECEIVER/HEAT/BRAYTON/GENERATOR	34.2 %
RECEIVER/MHD GENERATOR	55.0 %
RECEIVER/PROPULSION (100 % THEORETICAL)	50.0 %

LASER POWER TRANSMISSION APPLICATIONS

- 0 VERY LOW EARTH ORBIT SATELLITE -- DRAG REDUCTION
- 0 OTV (LEO TO GEO) -- WEIGHT REDUCTION
- 0 MARS -- SCIENTIFIC PROBES
- 0 DEEP SPACE SATELLITE -- PRIME POWER SUPPLY
- 0 SPACE PROCESSING/MANUFACTURING



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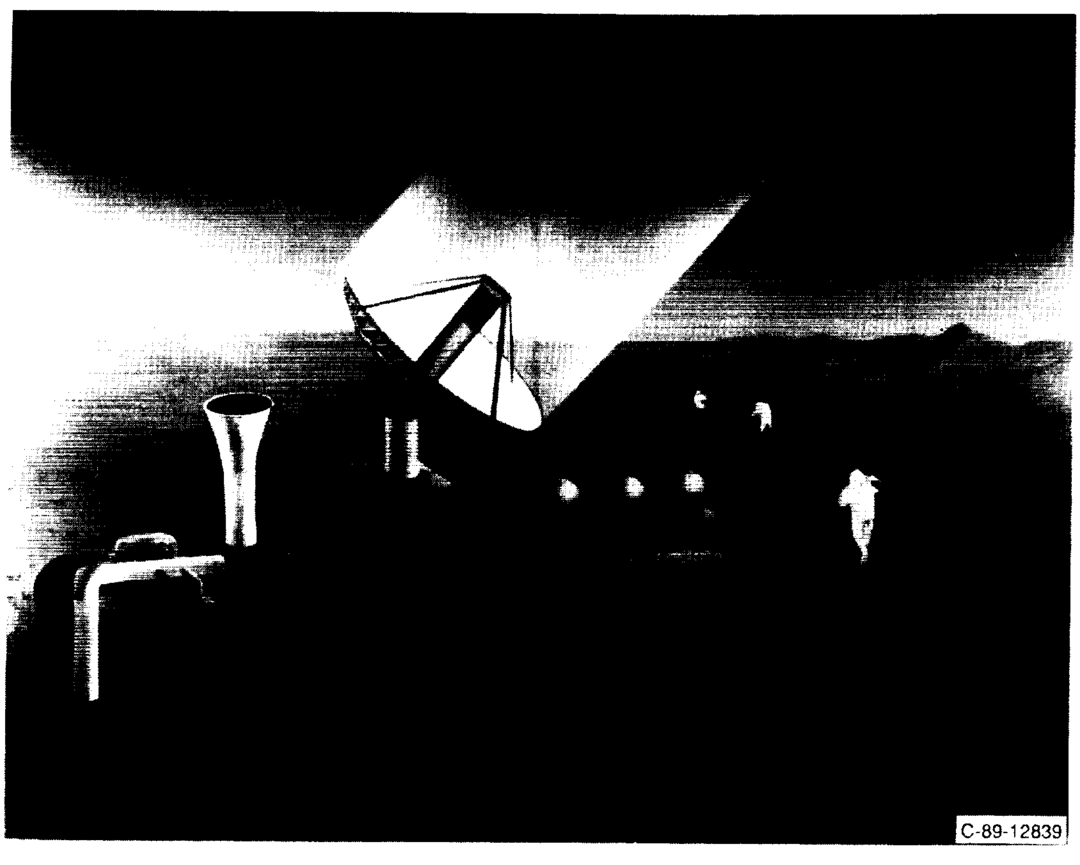

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MILESTONES

0	BEAM TRANSMISSION CHARACTERIZATION	5/88
0	TEST OF MOPA SYSTEM	12/88
0	OTHER GAS LASER ALTERNATIVES Na_2, HgBr	12/88
0	Nd^{3+} LIQUID LASER EVALUATION	6/88
0	SOLID STATE LASER EVALUATION Nd^{3+}: YAG, Nd^{3+}: GSGG, Nd^{3+}: YLF	3/88
0	PREFLIGHT EXPERIMENT GROUND TESTING	3/89
0	FLIGHT EXPERIMENT -- PLAN/DESIGN	?

SUMMARY AND CONCLUSION

0 SPACE-BORNE SOLAR-PUMPED LASER SYSTEMS ARE VIABLE OPTIONS FOR LASERS FOR FREE SPACE POWER TRANSMISSION. PRIME POWER SOURCE, SUN, IS FREE AND THE SYSTEM WITH 1.3- μm WAVELENGTH IS SUITABLE FOR TRANSMISSION OVER 1000 KM (LEO-GEO DISTANCE).

0 SOLAR-PUMPED IODINE LASER SYSTEM HAS SCALABILITY AND LIGHT WEIGHT (30 TONS/MW) SUITABLE FOR SPACE-BASED OPERATION.

0 DOIDE LASER ARRAYS DRIVEN BY SOLAR PANELS OR SOLAR DYNAMIC GENERATORS COULD BE ANOTHER CANDIDATE FOR THE SPACE-BASED LASER SYSTEM IF BEAM PROFILE CONTROL FOR THE LONG DISTANCE TRANSMISSION IS POSSIBLE.

0 IODINE LASER PROGRAM PROGRESSED STEADILY SINCE 1980 AND FLIGHT EXPERIMENT PROPOSED FOR 1990'S.

REFERENCES

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