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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution unlimited.
AD-A200 259 (S)	5. MONITORING ORGANIZATION REPORT NUMBER(S): AFOSR-TR- 88-1052
6a. NAME OF PERFORMING ORGANIZATION: SUNY/Stony Brook — 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: AFOSR/NE
6c. ADDRESS (City, State and ZIP Code): Dept. of Physics, SUNY, Stony Brook, NY 11794	7b. ADDRESS (City, State and ZIP Code): Bolling AFB, Washington, D.C. 20332
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: AFOSR/NE — 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: ~~AFOSR850205~~ AFOSR-85-0205
8c. ADDRESS (City, State and ZIP Code): Bolling AFB, Washington, D.C. 20332	10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
61102F	2305	C3	

DTIC ELECTE OCT 1 1 1988 D E

11. TITLE (Include Security Classification) Millimeter Wave Generation Using Josephson Junction Arrays

12. PERSONAL AUTHOR(S)
James Lukens

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Scientific (Final)	FROM 5/1/85 TO 6/30/88	88/7/31	

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	Millimeter wave generation
			Josephson junctions

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Studies have been carried out to develop methods to couple Josephson junction oscillators at frequencies near 100GHz so as to demonstrate the feasibility of Josephson effect sources of reasonable power and impedance. Phase-locking of junctions separated by greater than a wavelength and coupled through microstrip line has been demonstrated and found in accord with theory. Forty junction arrays operating at 100GHz and 350GHz using this phase-locking scheme have been tested. Both series and parallel biasing of the junctions have been tested. It has been established that a total critical current spread of less than 10% is required for complete phase-locking with series bias. For parallel biased arrays with a critical current spread of 20%, all junctions locked in-phase providing coherent addition of power to the 20 Ohm load.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL
~~James Lukens~~ Weinstock	202-767-4931	NE

DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE.

SECURITY CLASSIFICATION OF THIS PAGE

AFOSR-85-0205

AFOSR-TR- 88-1052

MILLIMETER WAVE GENERATION USING JOSEPHSON JUNCTION ARRAYS

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31 July 1988

Final Scientific Report for Period 1 May 1985 – 30 June 1988

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88 1011 086

Millimeter Wave Generation Using Josephson Junction Arrays

Final Technical Report

Grant AFOSR 850205

Statement of Work

A) Methods will be studied to achieve coherence in large series biased arrays including resonantly coupled arrays.

B) Fabrication techniques will be developed to make such large scale arrays.

C) Measurements of the power and linewidth of mm wave Josephson radiation from these arrays will be made in order to determine the fundamental lower limits on radiation linewidth and the upper limits on radiated power.

Studies have been carried out to determine design parameters for distributed arrays of Josephson junctions to be used as spectrally pure sources near 100 GHz. Computer simulations have verified that proposed designs provide the required phase-locking and have determined the limits for the junction capacitance and the shunt inductance. The proper termination of the array transmission line to provide optimum phase-locking has been determined. Measurements have been made of the locking strength between two junctions coupled via a transmission line. Results are in agreement with predictions.

Work has been carried out in conjunction with NBS Boulder to test the suitability of conventional window junction fabrication technology for array sources. Several problems were revealed during these tests, including the difficulty of obtaining sufficiently low inductance shunt resistors. A technique was developed in this laboratory to fabricate lead alloy junctions with low shunt resistance and inductance which are suitable for use in array sources.

Arrays of 40 junctions coupled via a 20 Ω microstrip to an on chip 20 Ω load have been tested. The design frequency was 100GHz. The power delivered to the load was monitored by measuring the rf current through the load using the amplitude of the Josephson step in a detector junction adjacent to the load resistor. All junctions of the array were biased in series with a common bias current. The results of phase-locking experiments show that if all the junctions of such an array are to phase-lock, a maximum spread of 10% in the junctions' critical currents can be tolerated. The measured critical current variation of the test array was about 20%.

The power delivered to the load was monitored as a function of the operating frequency of the array and exhibited a sharp peak at 109GHz, falling to zero several GHz on either side of this peak. The peak power detected corresponded to the coherent sum of the powers from 20% of the junctions in the array. The measured distribution of critical currents in the arrays together with the direct measure from the detector junction of the range of current over which a junction could phase-lock to the rf current in the microstrip showed that only 20% of the junctions in the array were phase locked at resonance. Thus the major conclusion of this work is that the microstrip coupling scheme developed does in fact correctly phase-lock distributed arrays of junctions such that the load power is the coherent in-phase sum of the available power from the individual junctions. In subsequent work, parallel biasing has been used to reduce the effective scatter in the critical currents and achieve a load power of $1\mu W$, which is the coherent sum of the power from all forty junctions in the array. This further demonstrates the claim for the proper operation of the phase-locking scheme developed.

In additional work carried out under this grant, an electron beam lithography system has been developed using equipment purchased with funding from an AFOSR URIP. Specifically, beam control and computer interface hardware have been designed and built to convert an AMRAY SEM into a vector EBL system controlled by an HP workstation computer. This system is designed to generate patterns with tens of nanometer resolution over centimeter fields as will ultimately be required for high-powered array sources. It includes the capability to register multilayer EBL patterns.

PUBLICATIONS REPORTING WORK SUPPORTED BY
U.S. AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

J.E. Sauvageau, A.K. Jain, and J.E. Lukens, "Millimeter wave phase-locking in distributed Josephson arrays," Int'l. J. of Infrared & Millimeter Waves, 8, 1281 (1987).

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J.E. Lukens, A.K. Jain, and K-L. Wan, "Application of Josephson effect arrays for submillimeter sources," presented at NATO Advanced Study Institute on Superconducting Electronics, 1988.

Personnel associated with Air Force Office of Scientific Research project
AFOSR850205, MILLIMETER WAVE GENERATION
USING JOSEPHSON JUNCTION ARRAYS
5/1/85 – 6/30/88

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REPORT OF INVENTIONS AND SUBCONTRACTS

(Pursuant to "Patent Rights" Contract Clause) (See Instructions on Reverse Side.)

FORM APPROVED OMB NO. 0704-0016

1a NAME OF CONTRACTOR/SUBCONTRACTOR	c CONTRACT NUMBER	2a NAME OF GOVERNMENT PRIME CONTRACTOR	c CONTRACT NUMBER	3 TYPE OF REPORT (check one) ☐ INTERIM ☐ FINAL
b ADDRESS (include Zip Code)	d AWARD DATE (YYMMDD)	b ADDRESS (include Zip Code)	d AWARD DATE (YYMMDD)	4 REPORTING PERIOD (YYMMDD) FROM: TO:

SECTION I - SUBJECT INVENTIONS

5 "SUBJECT INVENTIONS" REQUIRED TO BE REPORTED BY CONTRACTOR/SUBCONTRACTOR *(If "None", so state)*

a NAME OF INVENTOR(S) (Last, First, M.I.)	b TITLE OF INVENTION(S)	c DISCLOSURE NO., PATENT APPLICATION SERIAL NO. OR PATENT NO.	d ELECTION TO FILE PATENT APPLICATIONS: UNITED STATES		FOREIGN		e CONFIRMATORY INSTRUMENT OR ASSIGNMENT FORWARDED TO CONTRACTING OFFICER	
			YES	NO	YES	NO	YES	NO
None								

f EMPLOYER OF INVENTOR(S) NOT EMPLOYED BY CONTRACTOR/SUBCONTRACTOR		g ELECTED FOREIGN COUNTRIES IN WHICH A PATENT APPLICATION WILL BE FILED	
i NAME OF INVENTOR (Last, First, M.I.)	i NAME OF INVENTOR (Last, First, M.I.)	i TITLE OF INVENTION	ii FOREIGN COUNTRIES OF PATENT APPLICATION
ii NAME OF EMPLOYER	ii NAME OF EMPLOYER		
iii ADDRESS OF EMPLOYER (include Zip Code)	iii ADDRESS OF EMPLOYER (include Zip Code)		

SECTION II - SUBCONTRACTS (Containing a "Patent Rights" clause)

6 SUBCONTRACTS AWARDED BY CONTRACTOR/SUBCONTRACTOR *(If "None", so state)*

a NAME OF SUBCONTRACTOR(S)	b ADDRESS (include Zip Code)	c SUBCONTRACT NO.(S)	d DAR "PATENT RIGHTS": CLAUSE NO.	DATE (YYMM)	e DESCRIPTION OF WORK TO BE PERFORMED UNDER SUBCONTRACT(S)	f SUBCONTRACT DATES (YYMMDD): AWARD	ESTIMATED COMPLETION

SECTION III - CERTIFICATION

7 CERTIFICATION OF REPORT BY CONTRACTOR/SUBCONTRACTOR *(Not required if ☐ Small Business or ☐ Non-Profit organization.) (Check appropriate box)*

a NAME OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL (Last, First, M.I.)

b TITLE

c. I certify that the reporting party has procedures for prompt identification and timely disclosure of "Subject Inventions," that such procedures have been followed and that all "Subject Inventions" have been reported.

SIGNATURE OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL

DATE (YYMMDD): 8/31/88

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