A 60-GHz Efficiency-Enhanced On-Chip Dipole Antenna Using Helium-3 Ion Implantation Process

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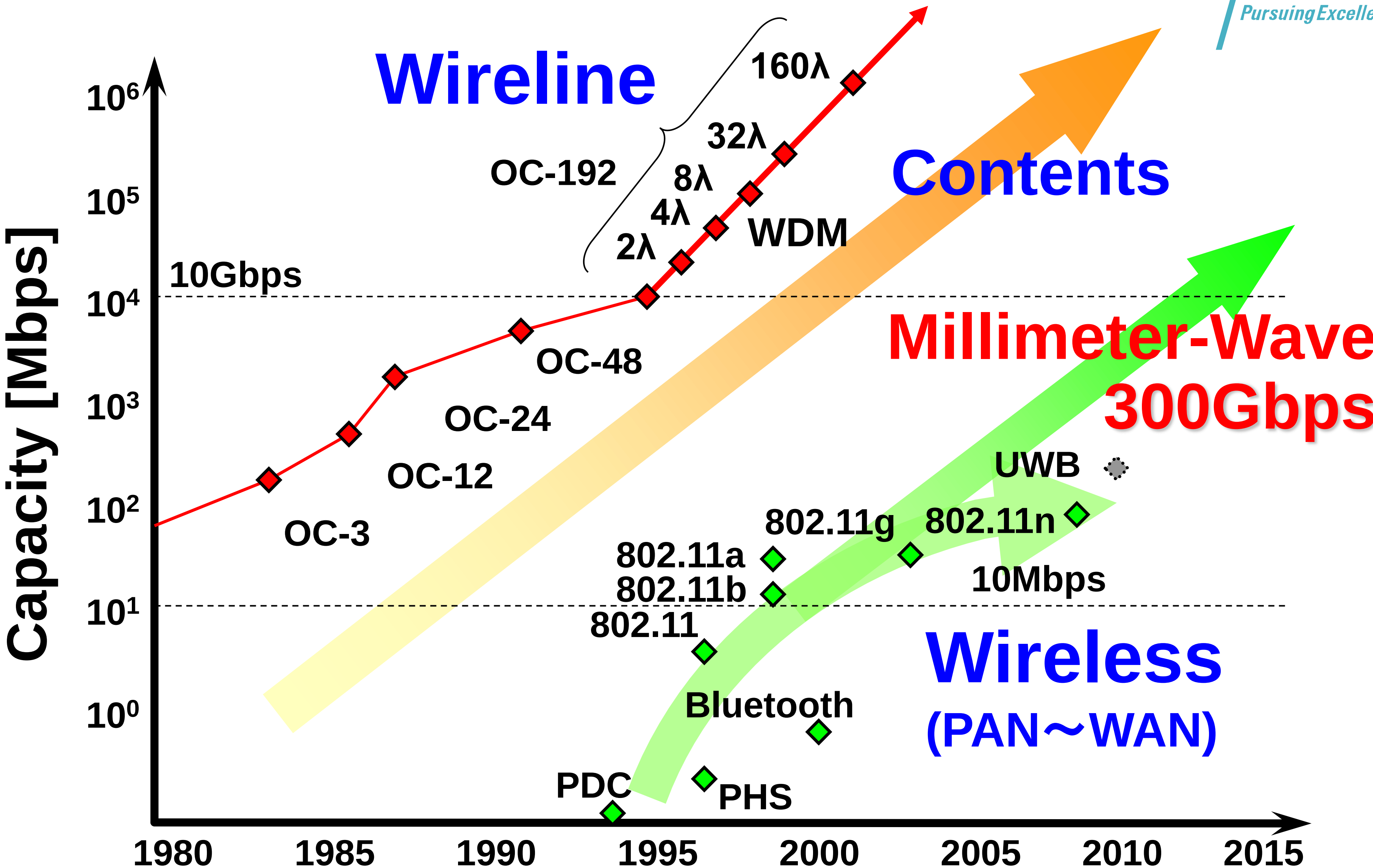
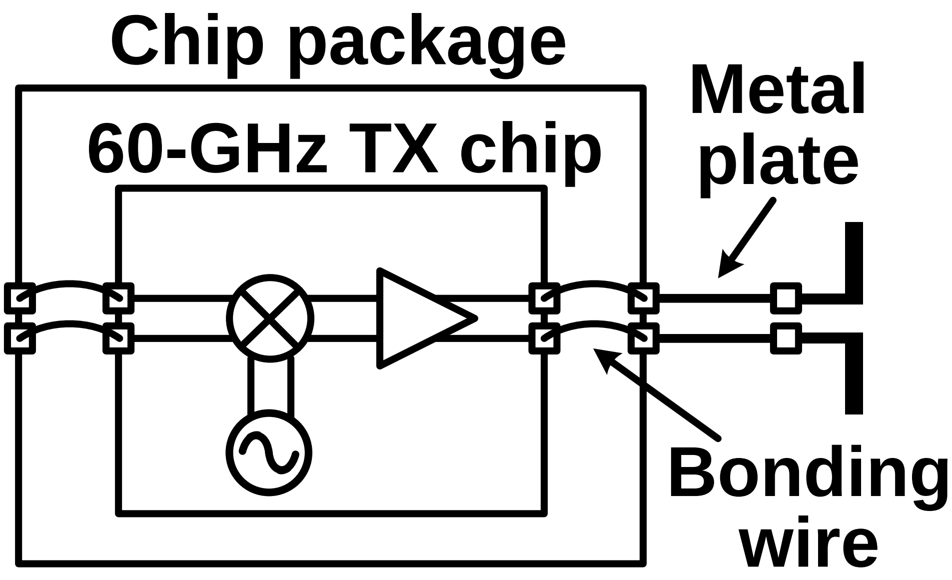
Outline

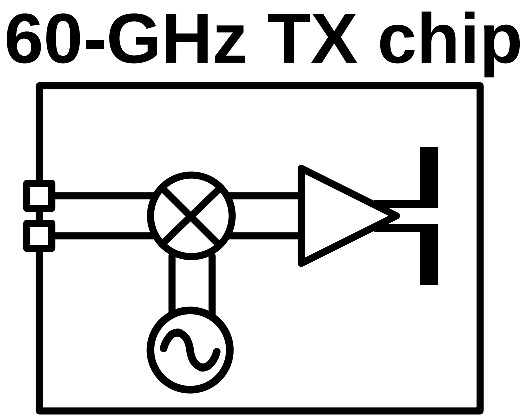
- 60-GHz Application and CMOS On-Chip Antenna
- Conventional Solutions
- Proposed On-Chip Antenna using Helium-3 Ion Irradiation
- Performance Comparison and Conclusions

Motivation


Wireline
Contents
Millimeter-Wave
300Gbps
Wireless
(PAN～WAN)
Capacity [Mbps]
10⁶
10⁵
10⁴
10³
10²
10¹
10⁰
10Gbps
10Mbps
OC-3
OC-12
OC-24
OC-48
OC-192
2λ
4λ
8λ
32λ
160λ
WDM
UWB
802.11n
802.11g
802.11a
802.11b
802.11
Bluetooth
PDC
PHS
1980
1985
1990
1995
2000
2005
2010
2015

60-GHz CMOS On-Chip Antenna





Off-chip antenna:

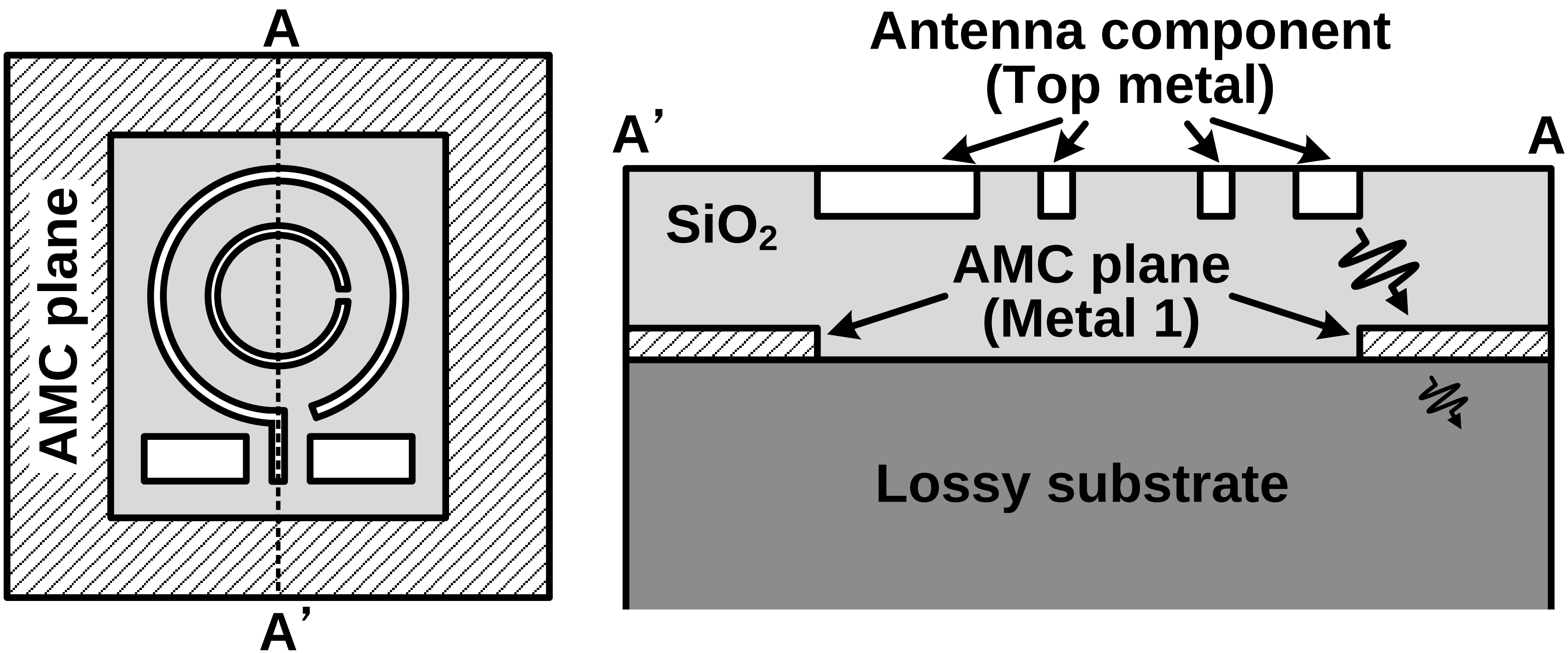
- ☺ High radiation gain
- ☹ parasitic components and loss for connection
- ☹ Degrade system performance and design flexibility

CMOS On-chip antenna:

- ☺ Much less parasitic and connection loss
- ☺ flexible design and monolithic integration
- ☹ Poor radiation gain due to lossy substrate

Conventional Solutions (1/2)

- **Artificial Magnetic Conductor (AMC)**



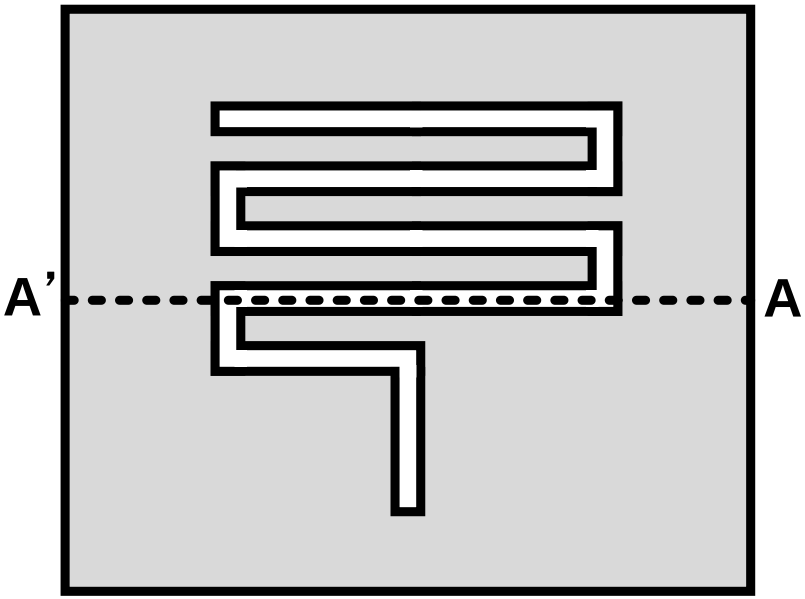
☺ **High-Z surface to prevent EM field induced in the lossy substrate**

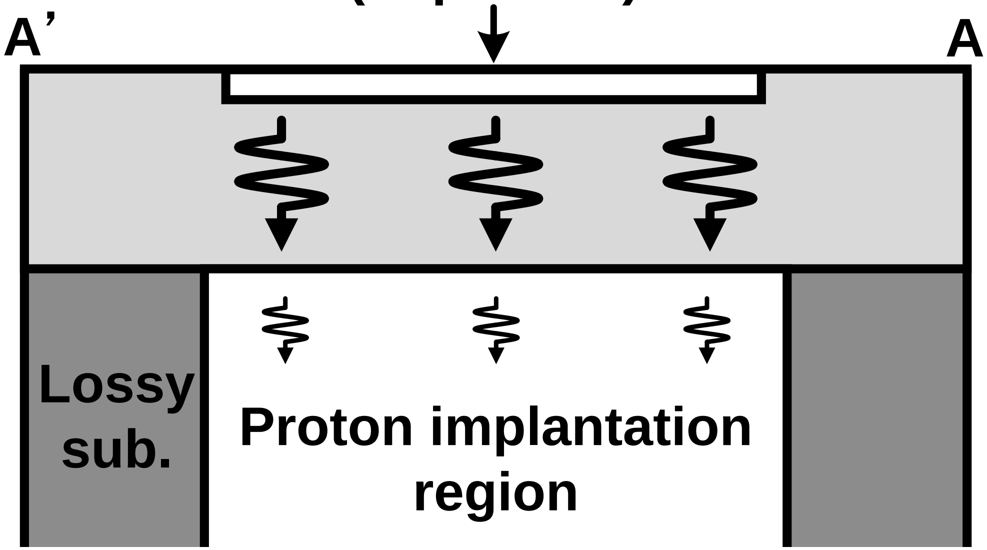
☹ **Large area for AMC pattern**

[1] X.-Y. Bao *et al*., ITAP 2012

Conventional Solutions (2/2)

- Proton implantation



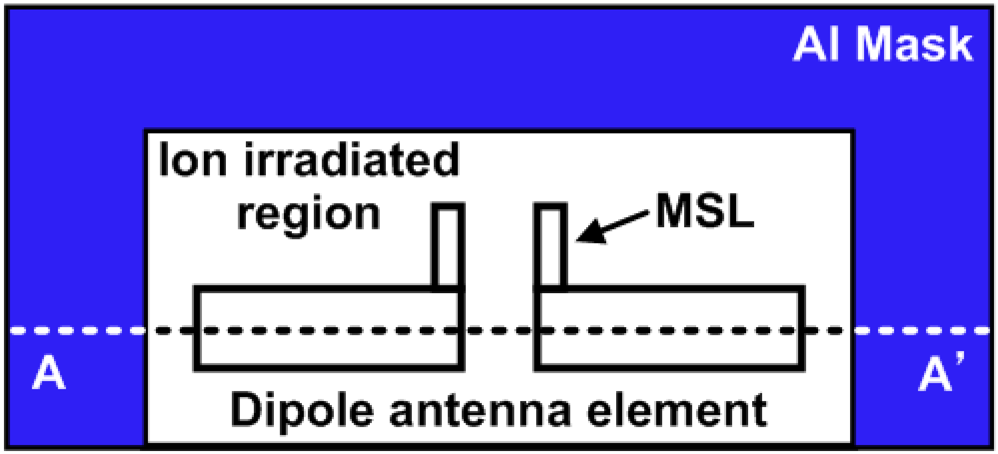


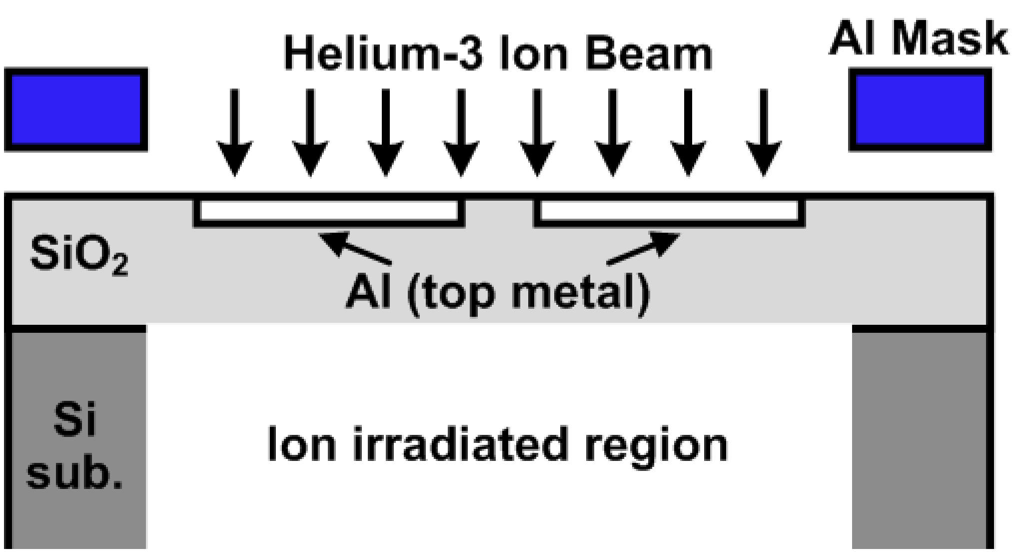
☺ Increase substrate resistivity to prevent induced EM field

☹ High dose amount and process cost

[2] K.-T. Chan *et al.*, IEDM 2001

Proposed Gain-Enhanced Antenna





Helium-3 ion irradiation

- ☺ **Increase substrate resistivity (≈$10^3 \Omega \cdot cm$)**
- ☺ **Less dose amount and process cost**
- ☺ **Less lateral scattering and higher reliability**

Helium-3 Bombardment Procedure

Confidential

Set wafer in plate

⇩

Move plate into chamber

⇩

Vacuum pumping

⇩

Ion irradiation

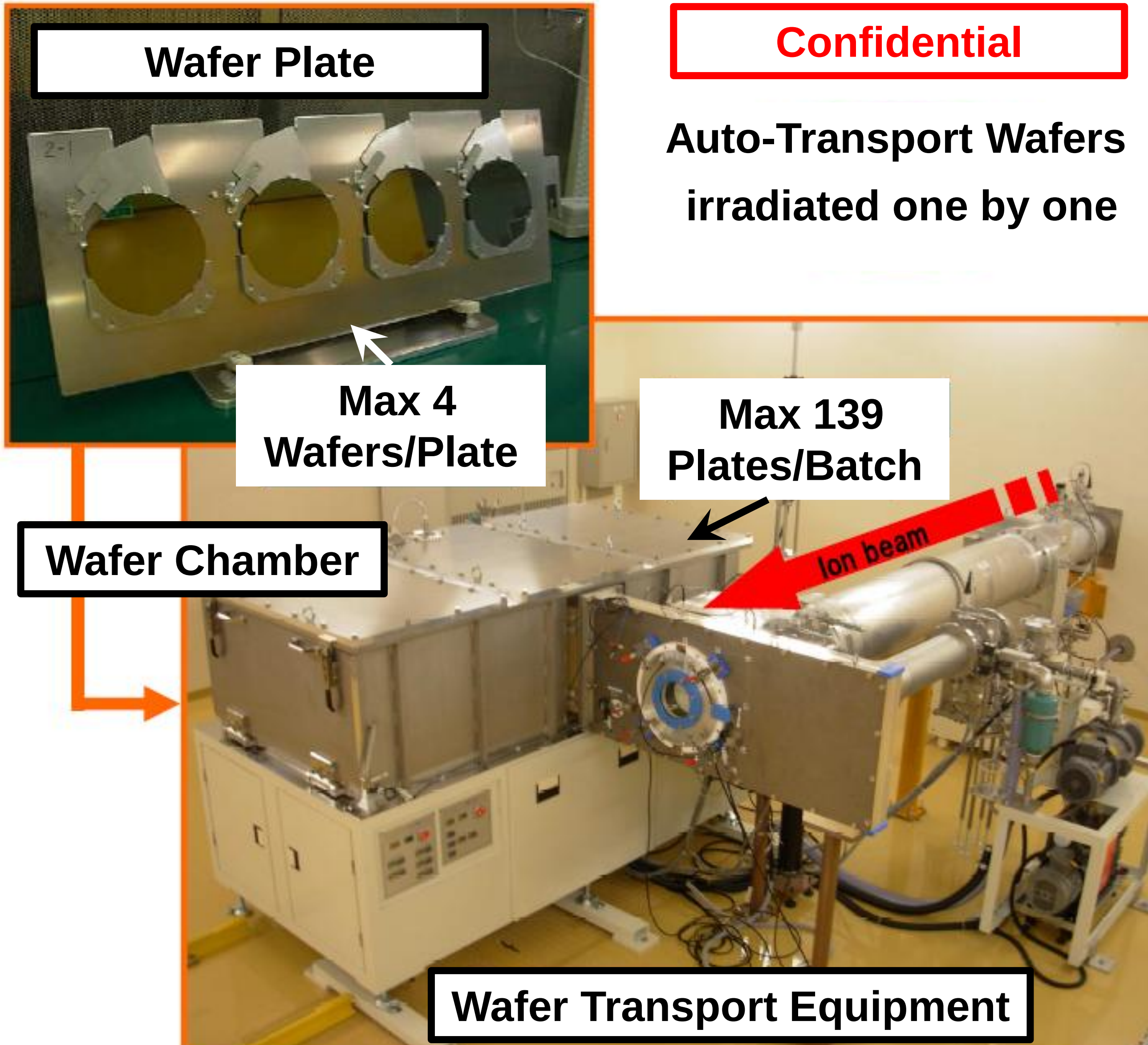
⇩

Air pumping

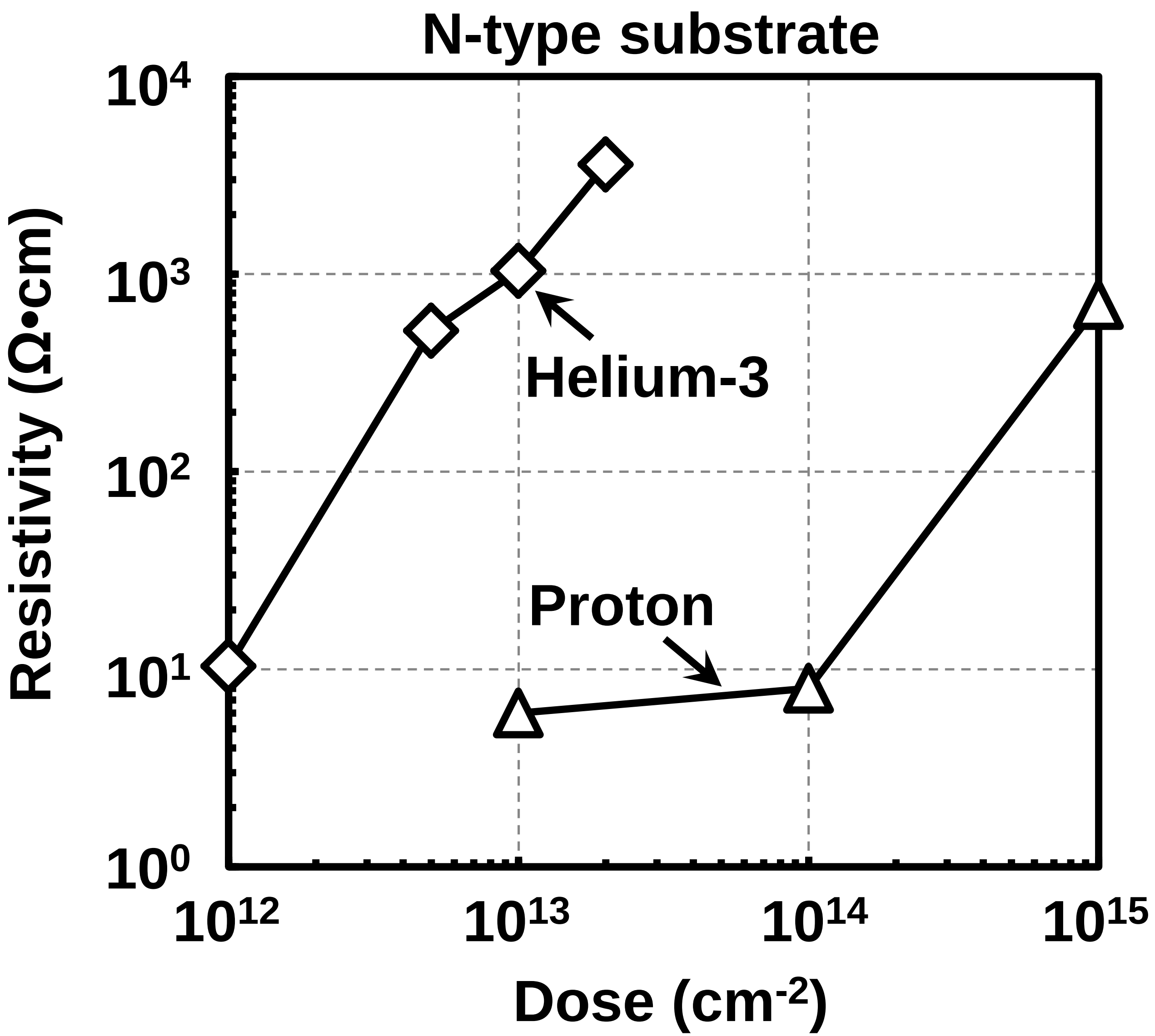
⇩

Move plate out of chamber

Auto-Transport Wafers irradiated one by one



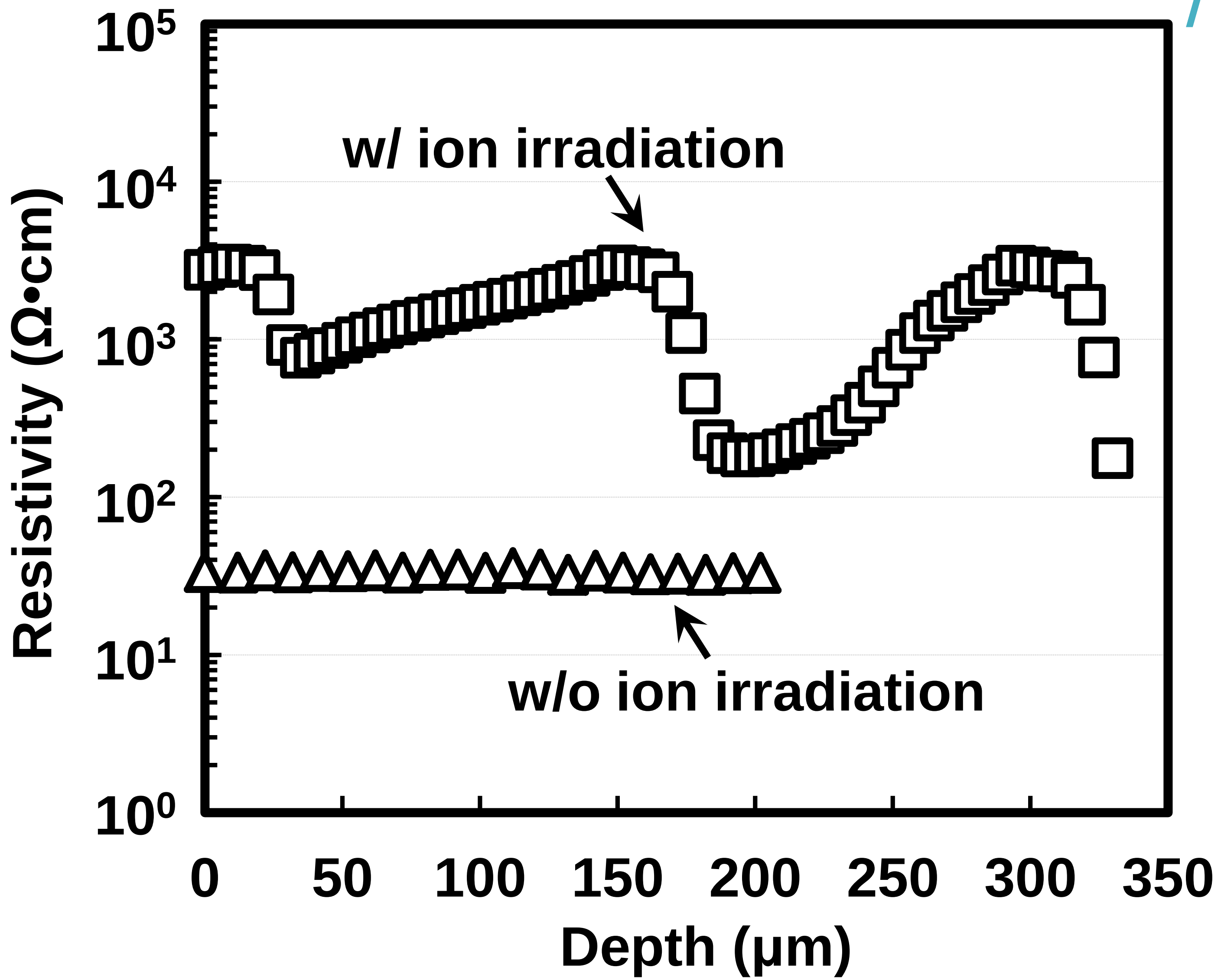
Measured Resistivity versus Dose



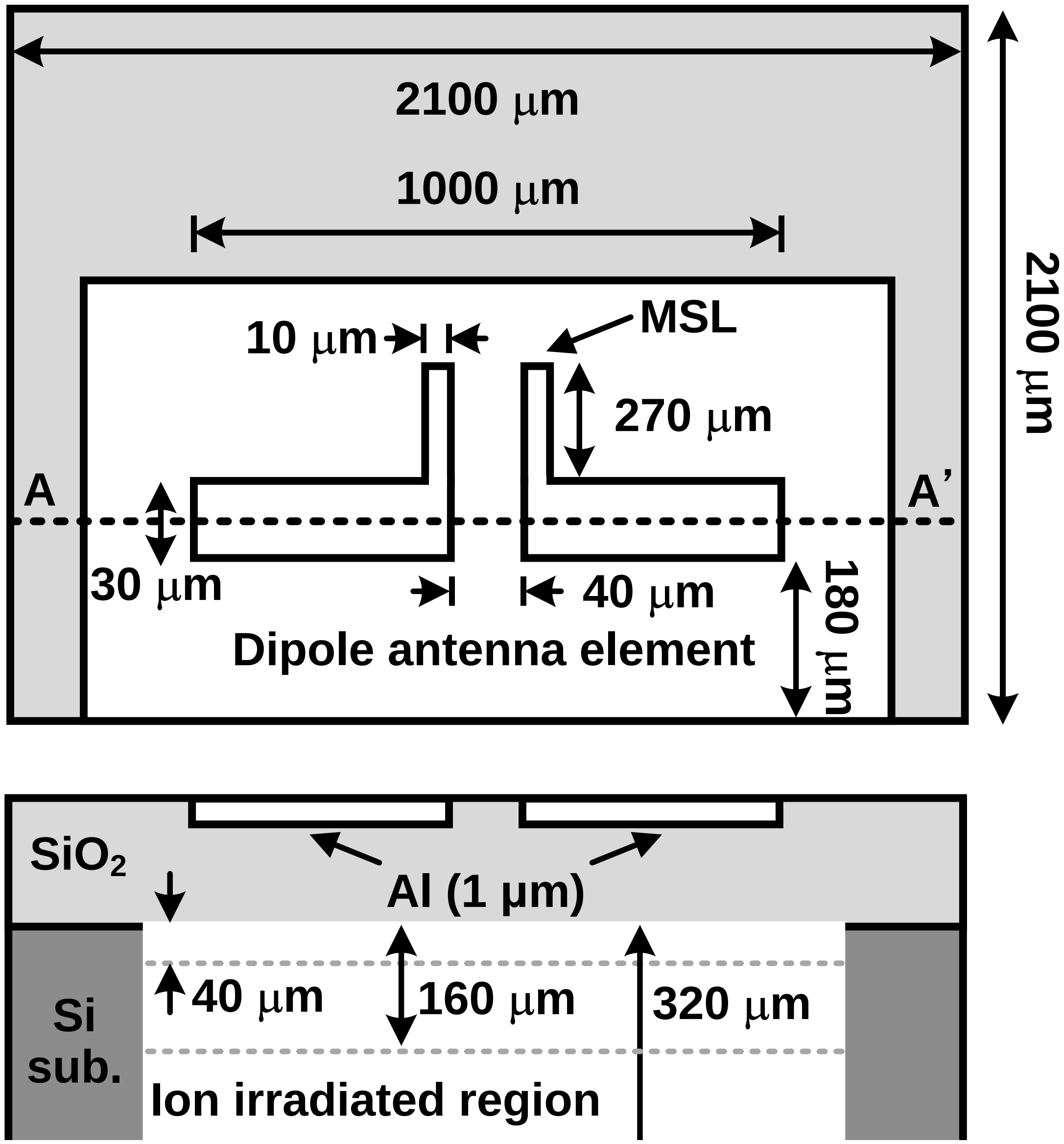
[3] N. Li *et al*., VLSI Technology 2014

[4] L.-S. Lee *et al*., ITED 2001

Measured Resistivity versus Depth

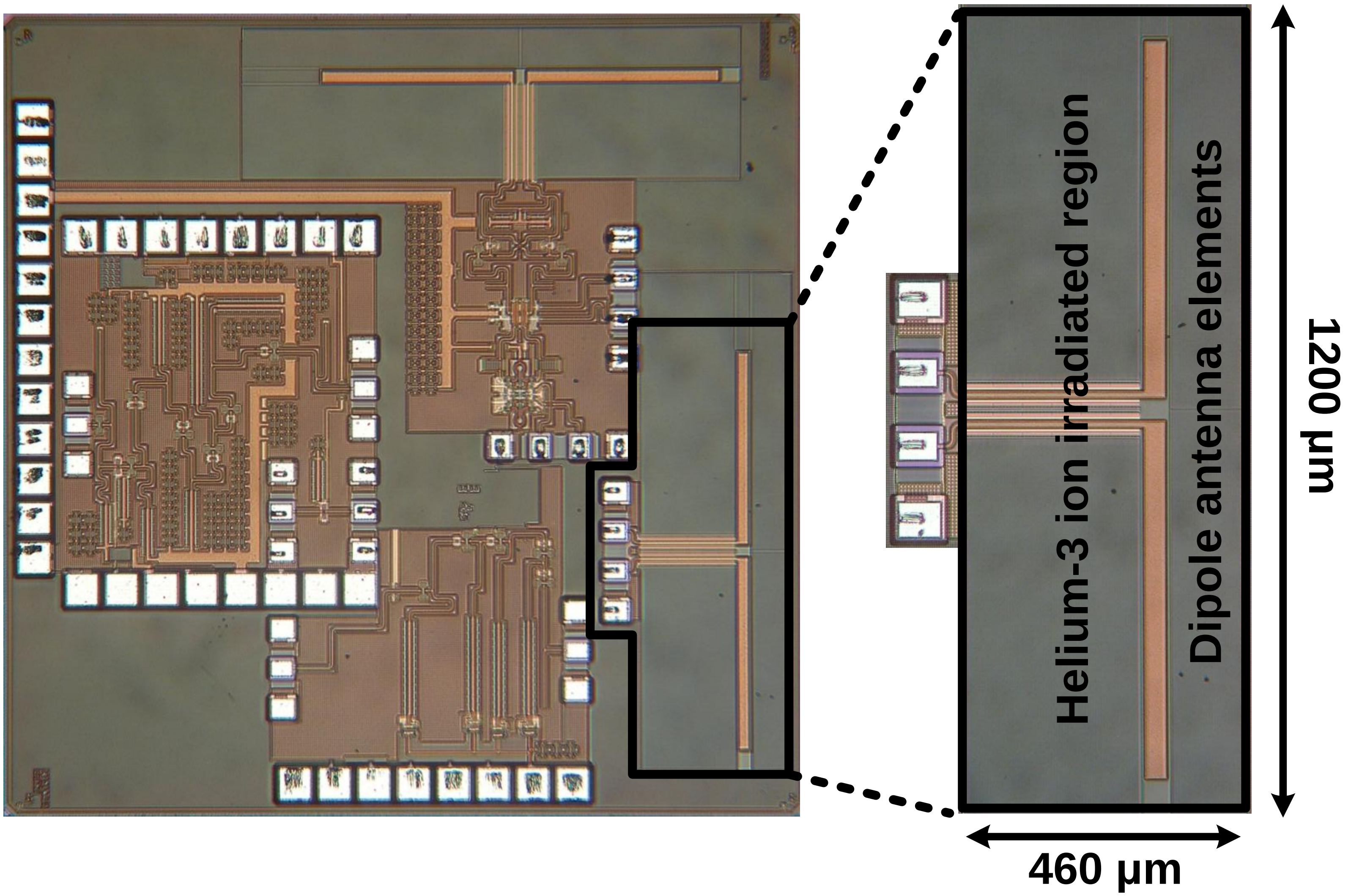


On-Chip Antenna Configuration

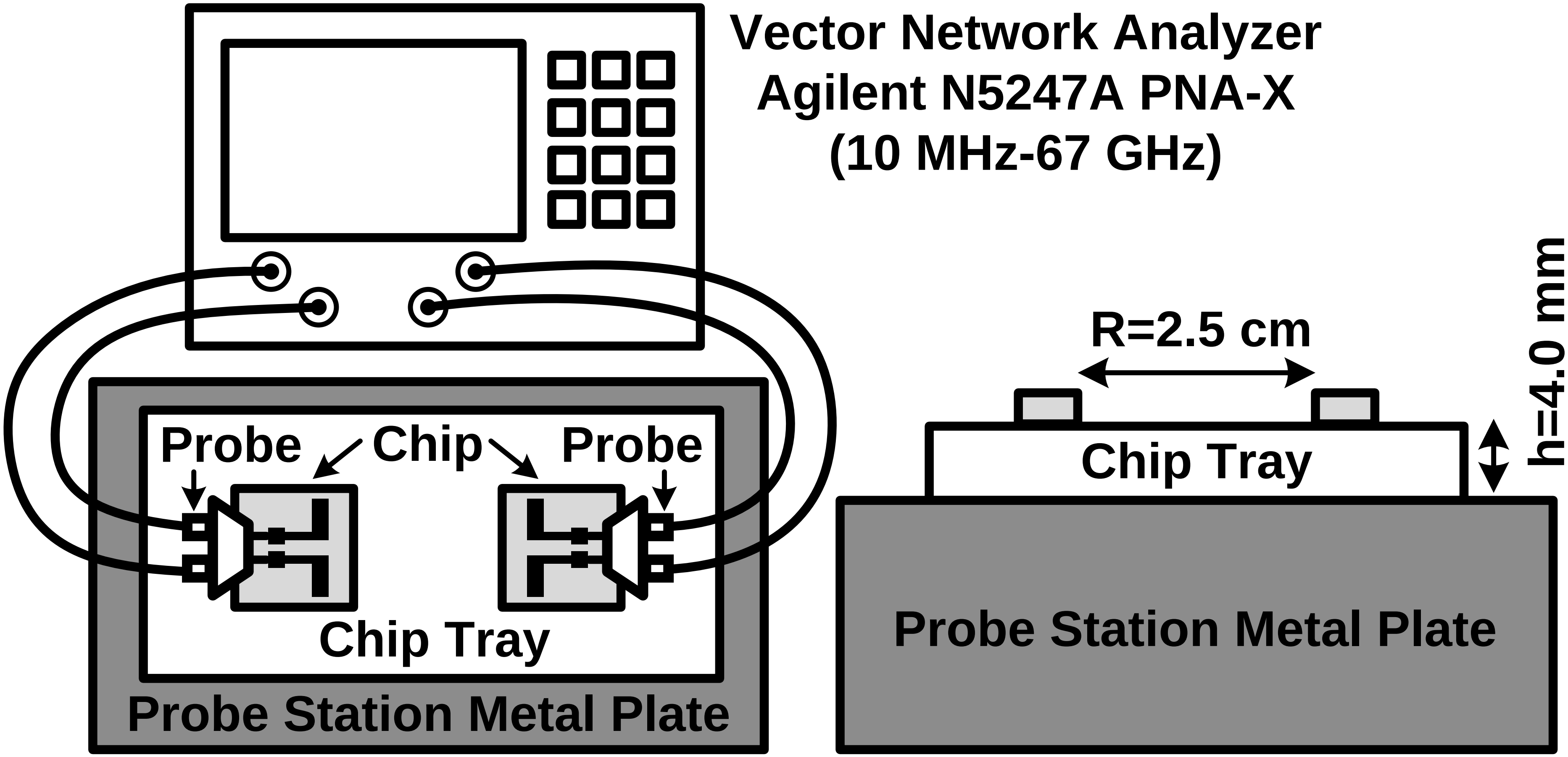


Die Micro-photograph

65 nm CMOS technology



Measurement Setup



Measured Antenna Gain

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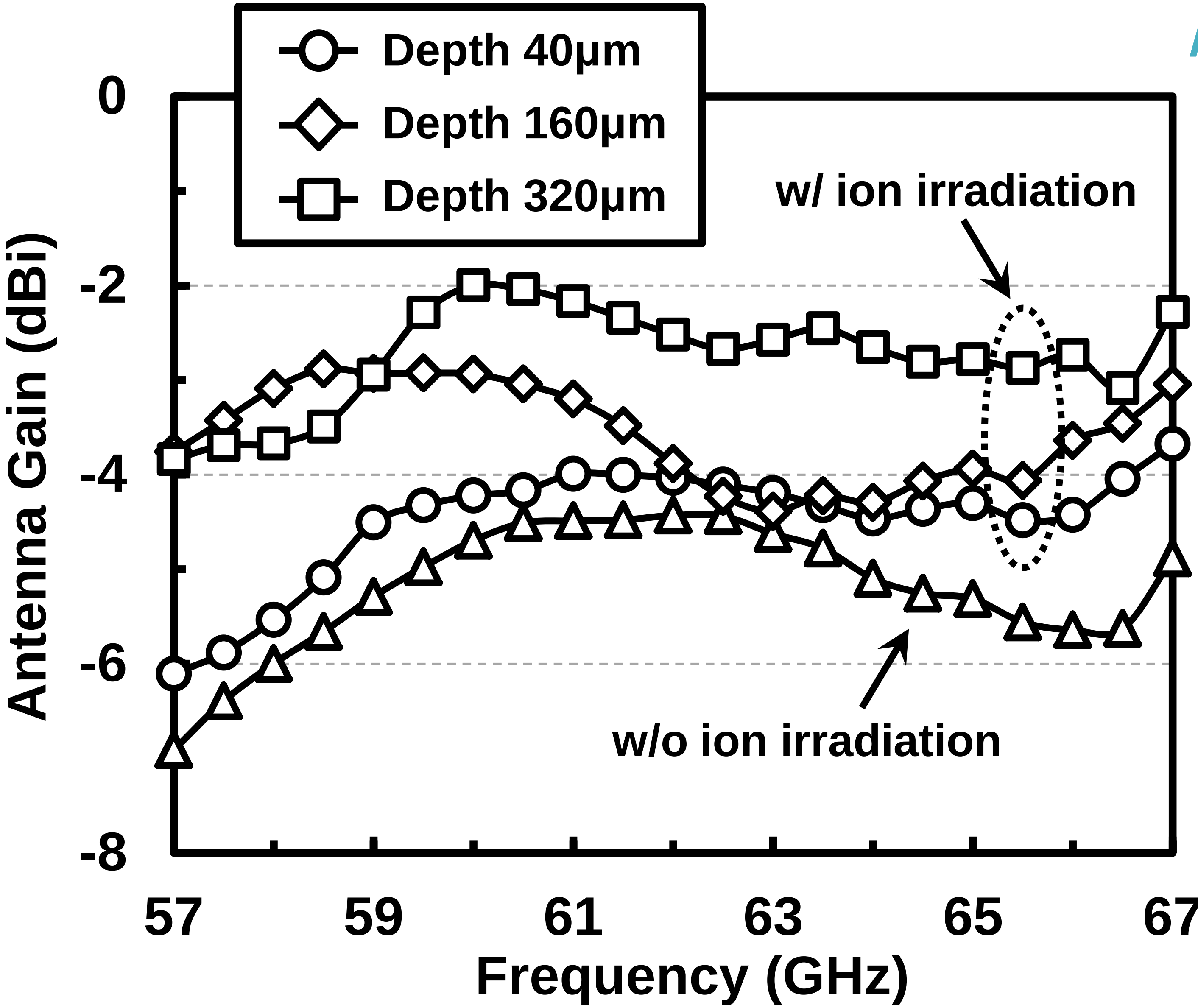
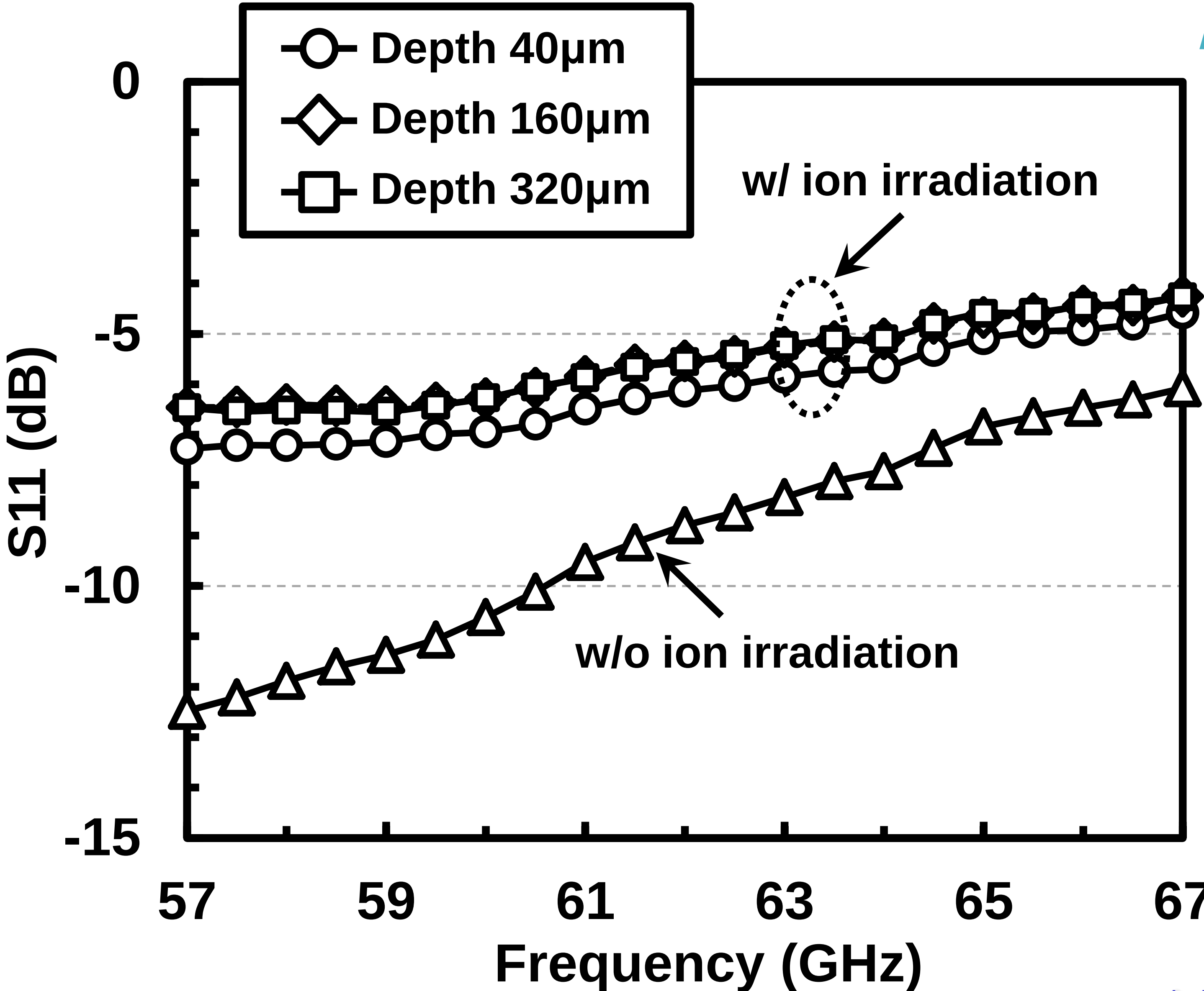


Measured S11



Performance Comparison

Ref.	CMOS Process	Type of on-chip antenna	Freq.	Antenna gain	Core area
This work	65 nm	Dipole with helium-3 ion irradiation	60 GHz	-2.0 dBi	0.48 mm^2
[1]	180 nm	Circularly polarized with AMC	65 GHz	-4.4 dBi	3.24 mm^2
[5]	180 nm	Yagi	60 GHz	-10.0 dBi	0.74 mm^2*
[6]	90 nm	Yagi with AMC	60 GHz	-7.2 dBi	1.04 mm^2
[7]	65 nm	Slot loop	60 GHz	-5.0 dBi*	0.64 mm^2*
[8]	Post-back-end-of-line (10 Ω•cm)	Inverted-F	61 GHz	-19.0 dBi	0.20 mm^2*
		Quasi-Yagi	65 GHz	-12.5 dBi	0.59 mm^2*

*Estimated from literature

[1] X.-Y. Bao *et al*., ITAP 2012
[5] H.-R. Chuang *et al*., ITED 2011
[6] H.-C. Kuo *et al*., ITMTT 2013
[7] L. Kong *et al*., ISSCC 2013
[8] Y.-P. Zhang *et al*., ITED 2005

Conclusions

- **60-GHz on-chip dipole antenna with helium-3 ion implantation technique**

- **Small dose amount ($3x10^{13}$ cm^{-2})**

- **Average 3-dB gain improvement across 57 GHz~67 GHz**

- **Peak gain of -2.0 dBi @ 60 GHz with 0.48 mm^2 area**

Thank you very much for your attention

Q & A