Realizing High Test Quality Goals with Smart Test Resource Usage

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Outline

- Motivation
- Fault models for high quality test
- Quality measurement beyond the fault models
- Experimental results – DFT techniques comparison
- Conclusions and future work

Motivation

- Practice DFT techniques for achieving highest test quality within test resource constraints
- Test quality goals
  - Improve both DC and AC defect detection coverage
  - Improve un-modeled defect detection coverage
- Test resource constraints
  - Limited test data volume
  - Reduced tester time
  - Manageable test pattern generation time

Fault Models for High Quality Test

- Commonly used at-speed fault models
  - Transition delay fault model
  - Path delay fault model
- Advanced fault models
  - Bridging faults, crosstalk faults …
  - Requiring physical information
  - Can only target a subset of possible fault locations
- Multiple-detect test set
  - Robustness
  - Applicable to both DC and AC fault models
  - Can we manage ATPG time and test data ?

High Test Quality

- Using different fault models
  - Stuck-at ATPG with single- and multiple-detect
  - Transition ATPG with single- and multiple-detect
  - Path delay ATPG
- Quality measurement for test sets
  - Test coverage is not sufficient
  - Need metric beyond test coverage
  - Two metrics used:
    - Bridging Fault Estimate (BCE)
    - Fault Observation Estimate (FOE)

Metric for Multiple-detect Test Set

Bridging Coverage Estimate (BCE)

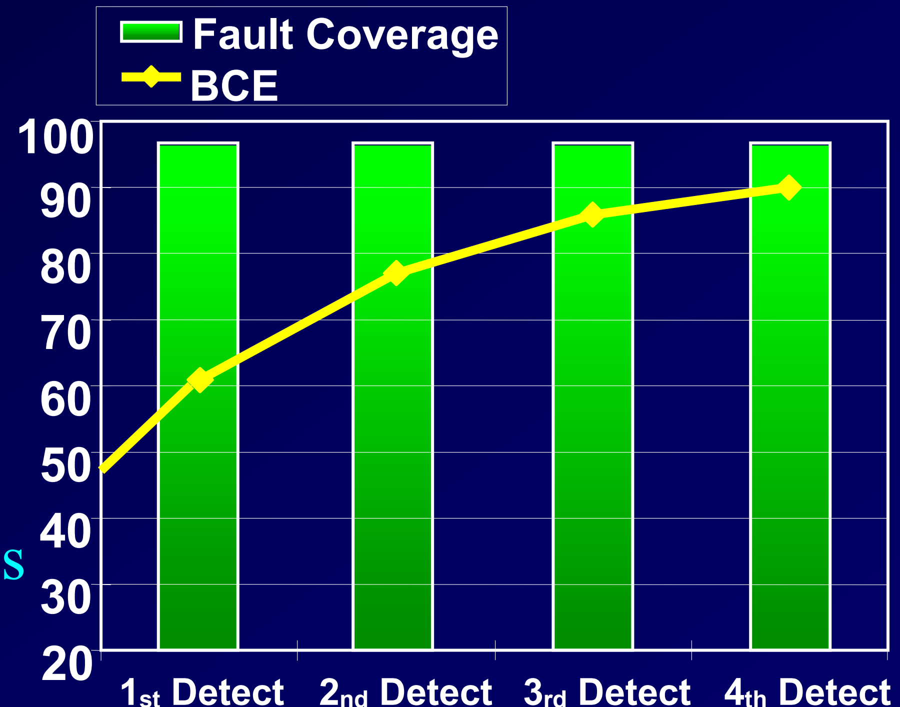
- Measure the detection probability of the bridging defect
- Multiple-detect stuck-at test set → static bridging defect
- Multiple-detect transition test set → resistive bridging defect

$$BCE = \sum_{i=1}^{n} \frac{f_i}{|F|} \bullet (1 - 2^{-i})$$

$|F|$: # of faults in design

f_i : # of faults detected i times

n : Max detection times



Metric for Multiple-detect Test Set

- **Fault Observation Estimate (*FOE*)**
  - Measure the observability of the test set
  - Increase the probability of at-speed defect detection

$$FOE = \sum_{f \in F} \left(1 - \left(1 - \frac{1}{op_{\max}(f)} \right)^n \right) \Big/ |F|$$

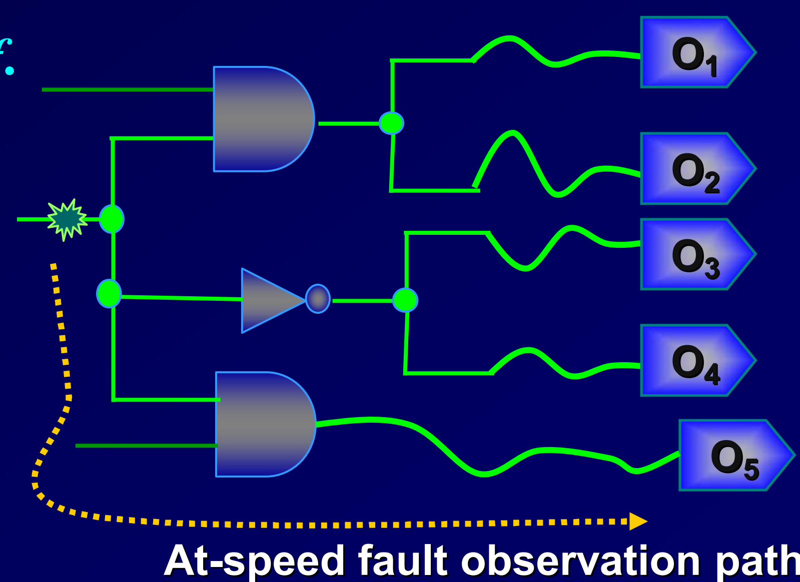
$op_{\max}(f)$: Max possible obs. points for f.
n: f detection times

Example:

1-detect FOE = 1-(1-1/5) = 20%

2-detect FOE = $1-(1-1/5)^2$ = 36%

3-detect FOE = $1-(1-1/5)^3$ = 49%



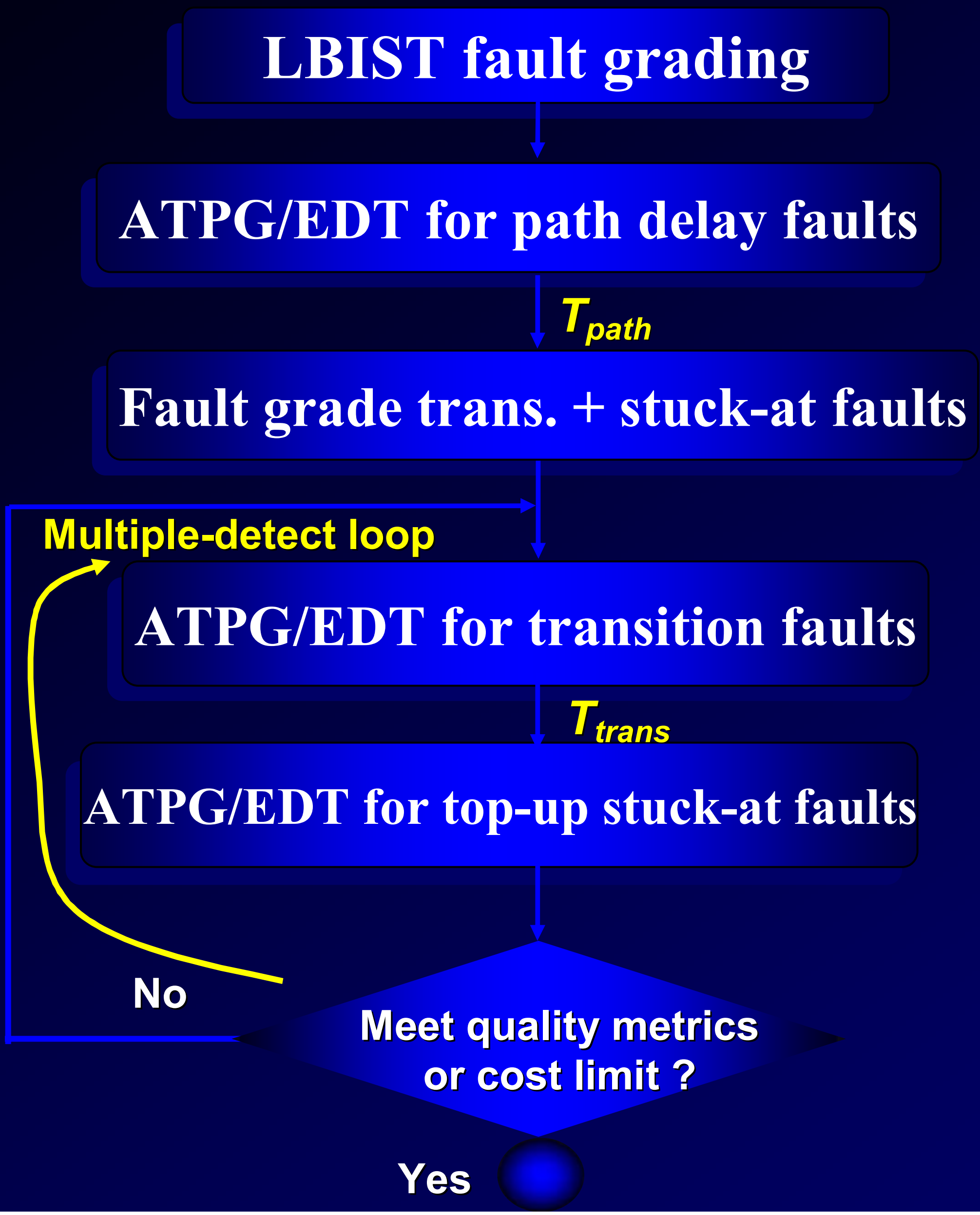
Test Cost

- Improving test quality by applying more fault models dramatically increases test volume
  - Transition test: 3-5X compared to stuck-at
  - Multiple-detect: nX compared to 1-detect
- Example
  - 1-detect stuck-at test set: 18.3M
  - 1-detect stuck-at and trans. test set: 61.6M
  - 5-detect stuck-at and trans. test set: 262.0M

DFT Techniques

- **ATPG**
  - Static and at-speed modeled defects
  - Multiple-detect of stuck-at and transition faults for certain un-modeled defects including bridging defects
- **EDT**
  - Compression technique for test volume and tester time reduction
  - Deterministic patterns applied through on-chip decompressor and compactor
  - Same high test quality
- **LBIST**
  - System test
  - Un-modeled and random defects

DFT Flow



- **Use multiple-detect fault sim. with *n* > max detect times**
- **Fault grade T_{path} and T_{trans} on stuck-at faults first**
- **User-specified criteria:**
  - **BCE**
  - **FOC**
  - **Test volume limit**

Design Example Characteristics

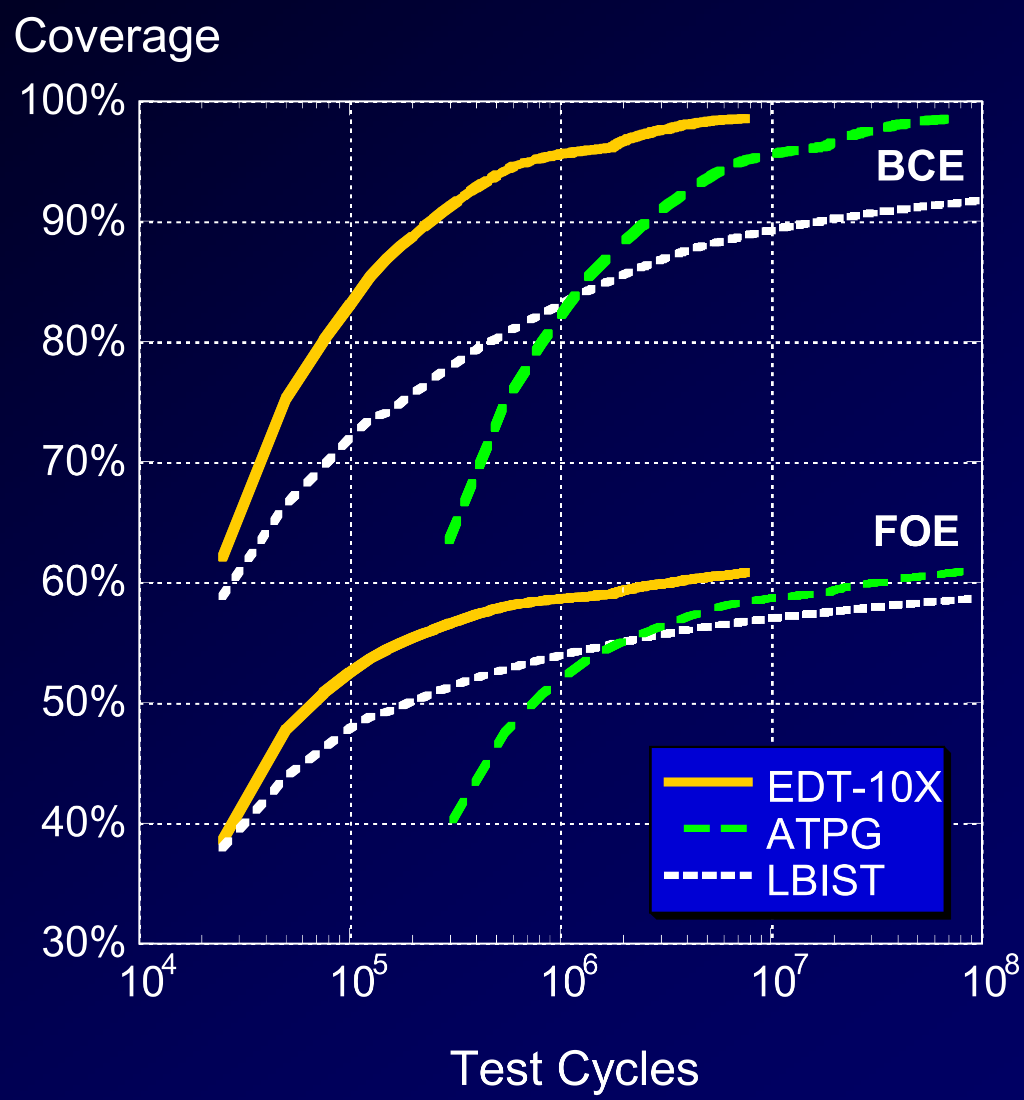
DFT Method	# external channels	# internal chains	# shift cycles	Overhead (k gates)
ATPG	10	10	8530	None
EDT 10X	10	100	780	2.5
LBIST	None	100	776	10

- **Gate count: 925 K**
- **Scan cells: 77K**

Test Results: Stuck-at

	n-detect	# pat.	# test cycles	TC (%)	BCE (%)	FOE (%)
ATPG	1	2.1k	18.3M	98.75	96.22	59.11
	5	9.5k	81.0M	98.76	98.58	60.86
EDT 10X	1	2.3k	1.8M	98.73	96.16	59.04
	5	9.9k	7.7M	98.75	98.56	60.78
LBIST		8.0k	6.4M	89.77	88.49	56.56
		128.0k	102.0M	92.39	91.76	58.71

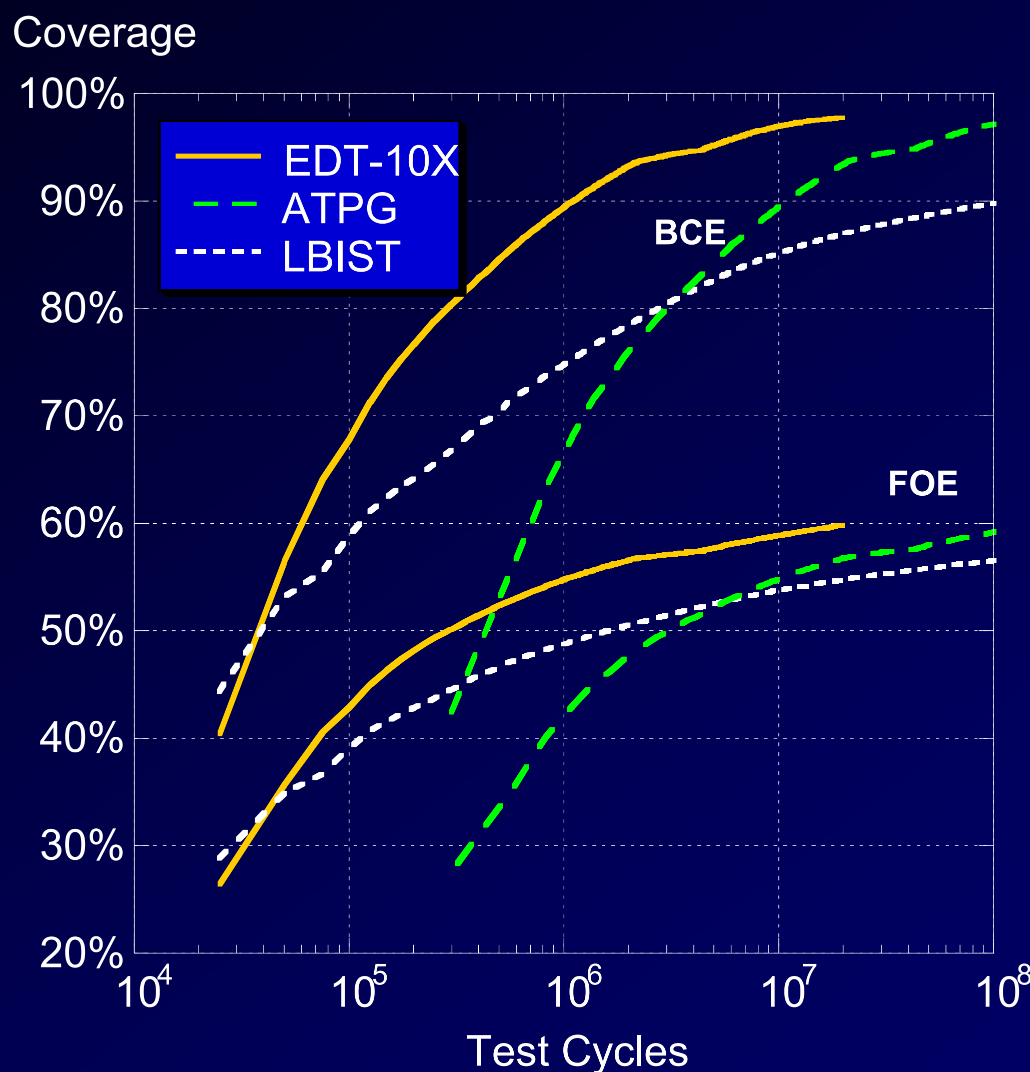
Test Quality: Stuck-at



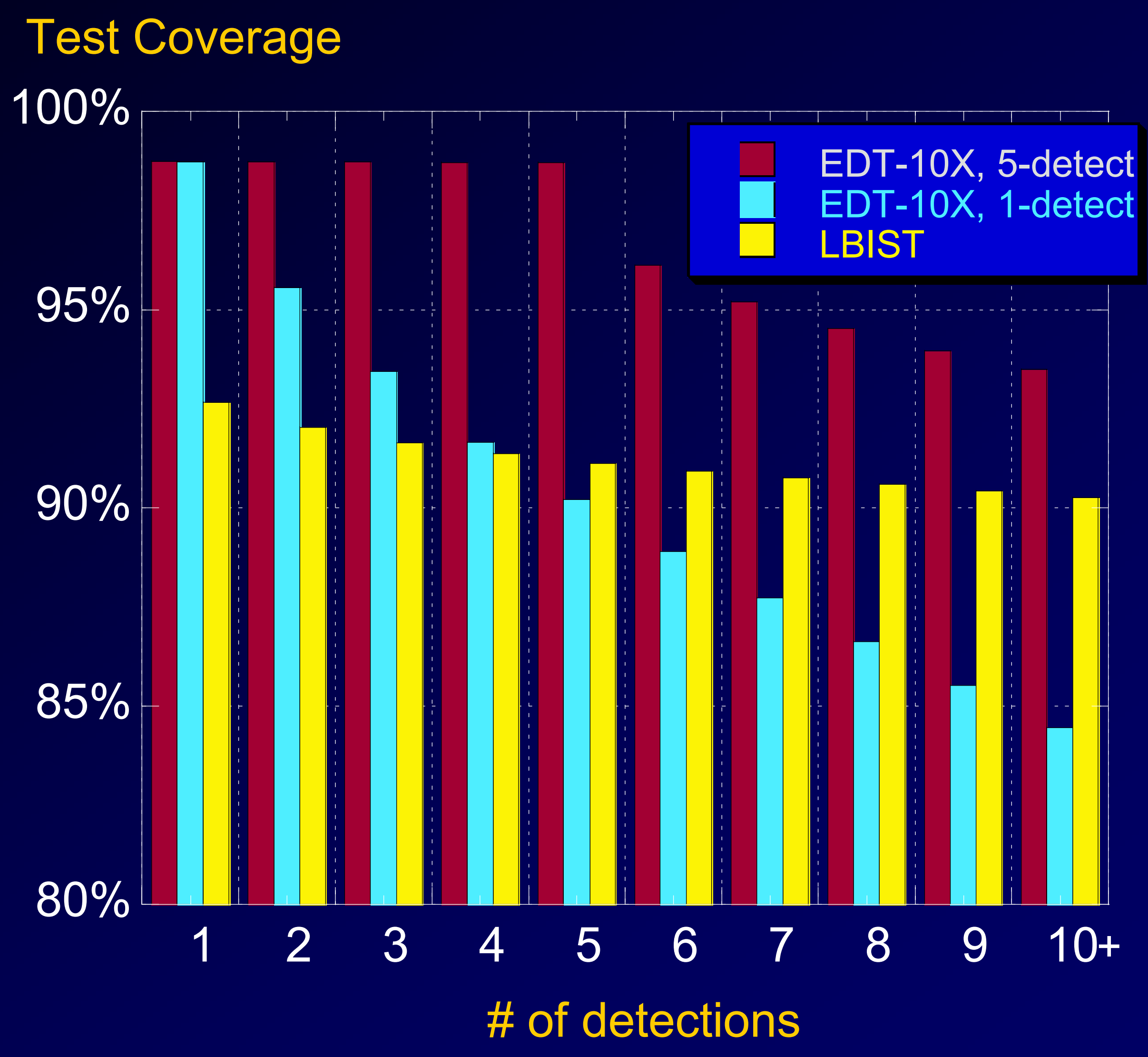
Test Results: Transition

	n-detect	# pat.	# test cycles	TC (%)	BCE (%)	FOE (%)
ATPG	1	5.1k	43.3M	97.94	94.91	57.65
	5	21.2k	181.0M	98.08	97.85	59.97
EDT 10X	1	5.7k	4.4M	97.87	94.80	57.46
	5	25.4k	19.8M	98.04	97.80	59.83
LBIST		8.0k	6.4M	85.96	83.69	53.01
		128.0k	102.0M	90.84	89.84	56.59

Test Quality: Transition



5-Detect Profile for EDT and LBIST



Conclusions & Future Work

- A recommended DFT flow
  - Achieve highest test quality
  - Meet test cost limit
    - Test data volume
    - Tester time
  - Require no physical information
- Future work
  - Correlate defect coverage with BCE and FOE
  - Evaluate the defect-oriented multiple-detect scheme

This presentation is located on
www.mentor.com/dft