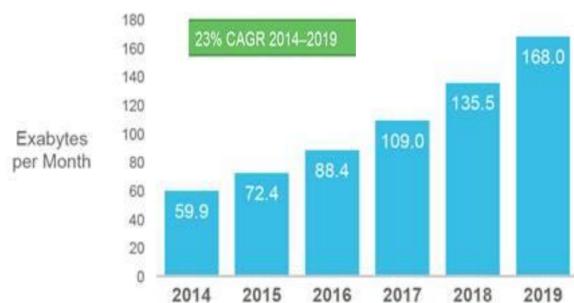


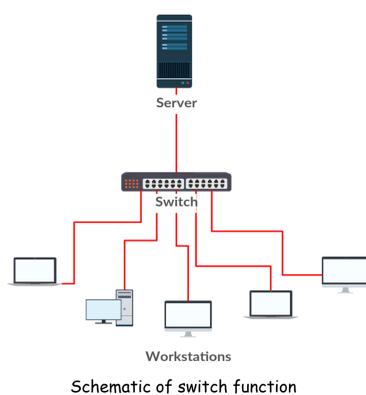
## Introduction

### Motivation

- Internet usage has exploded
- Data traffic expected to increase 300% between 2014 and 2019
- New high-bandwidth applications
  - Video-on-demand, video conferencing, online gaming
- Data traffic patterns are rapidly changing
  - Need dynamic technologies to handle changing data flow



IP traffic per month forecasts<sup>2</sup>  
Image courtesy of Cisco Visual Network, Inc



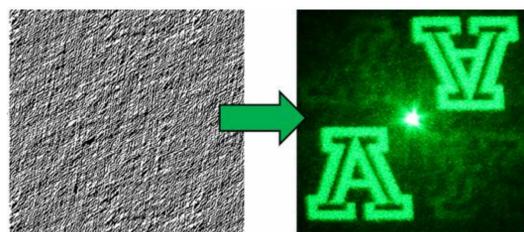
### Switches

- Switches- Reroute information, Interconnect different fibers
  - Historically: optical → electrical
    - optical signal
  - Bandwidth bottleneck, slow, rigid

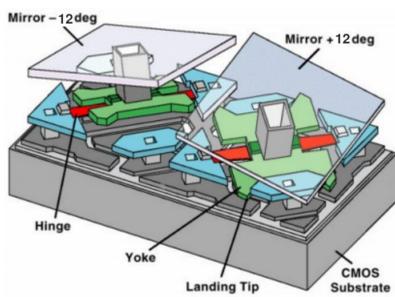
**GOAL: Design a 1xN switch whose performance is constant as a function of data rate**

## Diffraction-Based Optical Switch

- Digital micromirror device (DMD) with computer generated hologram (CGH) diffract light in predetermined pattern and acts as an active beam steering element
  - Protocol- and bandwidth-invariant
  - Fast (12 μs)
  - Decouples transmit and receive-side components



CGH and the resulting diffraction pattern



Close-up of two mirrors in a DMD  
Image courtesy of Texas Instruments

## Design

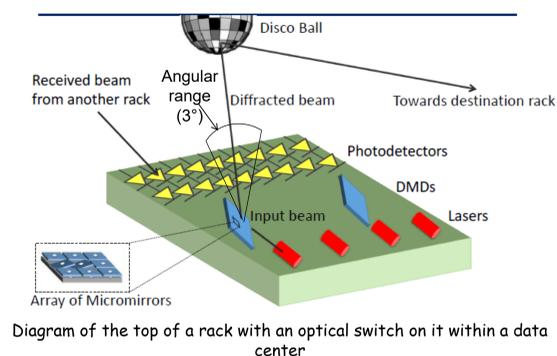
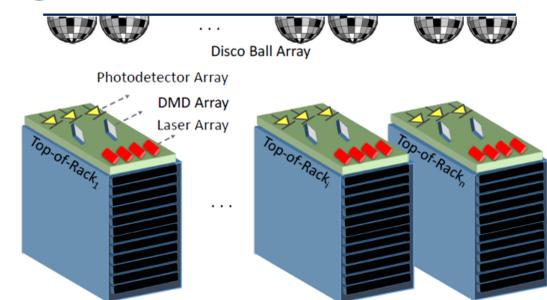


Diagram of the top of a rack with an optical switch on it within a data center



Mock-up of data center design with diffraction-based optical switches

### COMPONENTS:

- DMD with computer generated hologram:**
  - Diffracts light into some precalculated pattern
    - Acts as active steering element
  - Limited angular range (3°)
- “Disco ball” mirror assembly:**
  - Increases reach of switch
  - Redirects light from source to destination rack

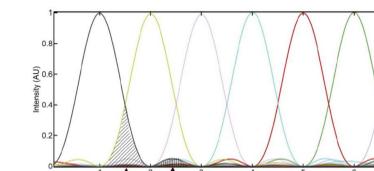
### PROPERTIES:

- Bandwidth-invariant**
- Rapid reconfiguration time**
- Allows for flexible topologies**
- Decouples the send- and receive-side components**
  - Independent scaling of outputs and inputs

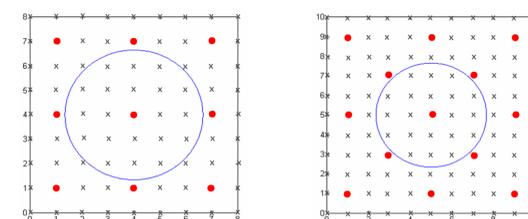
## Number of Accessible Locations

**GOAL: Determine the maximum number of accessible output ports**

- # of DMD pixels = maximum # possible diffracted beams
- However, need crosstalk, signal meant for one detector measured at another, to be below -40 dB (1000 times weaker)
  - Can't use all diffracted beams because the crosstalk between adjacent locations is too high



Adjacent beams diffracted by the DMD; crosstalk is equal to the area of overlap between beams

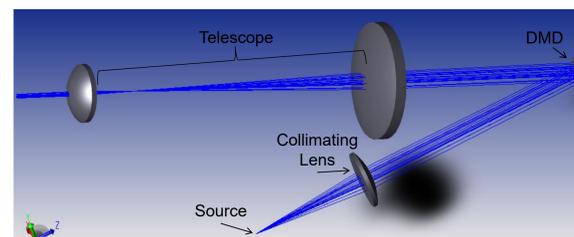


Square and parallelogram packing configurations. x's mark all possible diffracted beam locations, red spots mark selected outputs, circle marks minimum separation between beams for cross-talk to be below -40 dB.

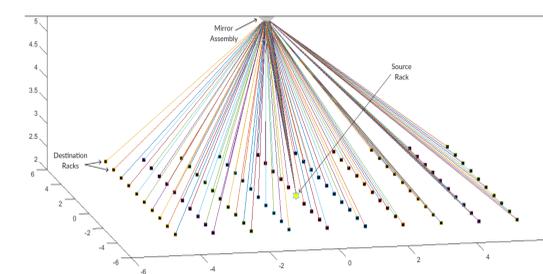
- Modeled and tested different packing configurations in MATLAB
- Parallelogram increases number of points by 12.5% over square configuration (44k to 50k)

## Modeling the System

- 1x100 switch was modeled and optimized in Zemax



Ray tracing diagram of portion of switch modeled in Zemax



Ray tracing diagram from source rack to destination racks for 1x100 diffraction-based optical switch

## References

- A. Miles; B. Lynn; P.-A. Blanche; J. Wissinger; D. Carothers; L. LaComb Jr.; R.A. Norwood; N. Peyghambarian. Optics Communications, vol. 334, pp 41-45, (2015).
- Cisco Visual Networking. "Cisco Global Cloud Index: Forecast and Methodology, 2012-2017, (White Paper)," Cisco, 2013 (16 June 2014).
- P.-A. Blanche; D. Carothers; J. Wissinger; N. Peyghambarian. SPIE Journal of Micro/Nanolithography, MEMS, and MOEMS (JM3), 13 (1), 01110 (2013).
- P.-A. Blanche. "Fast Optical Switch for Data Communication Applications". Presentation.

## Future Work

- Design mirror assembly in Solidworks and manufacture
- Experimentally test design
- Increase number of output ports

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