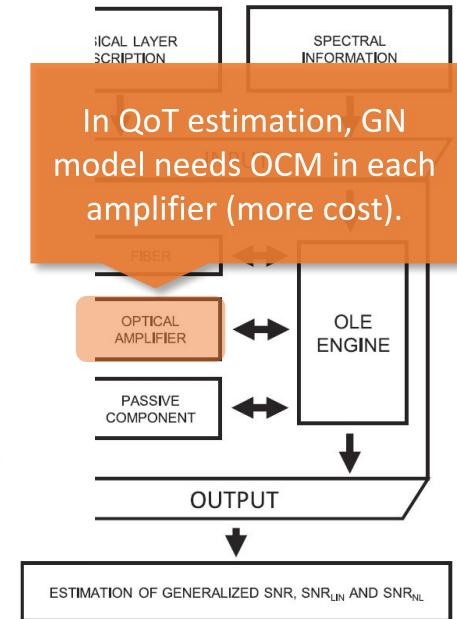
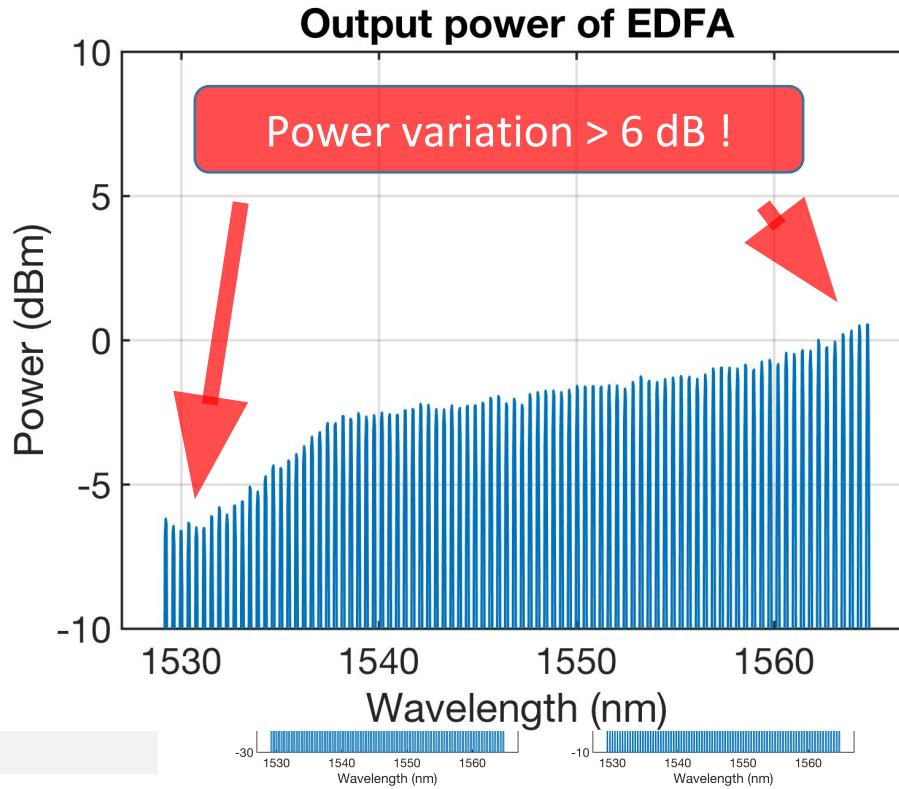
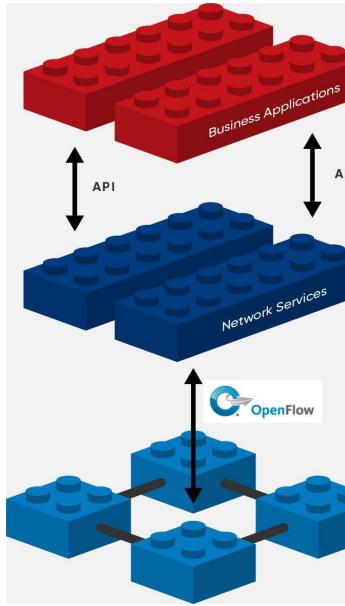


# Machine Learning Based Prediction of Erbium-Doped Fiber WDM Line Amplifier Gain Spectra

Shengxiang Zhu, Craig L. Guttermann,  
Weiyang Mo, Yao Li,  
Gil Zussman, Daniel C. Kilper



# Software-Defined Network in



Open Networking Foundation 2018

S. Zhu, et. al, OFC 2017

M. Filer, et. al, JLT 2018

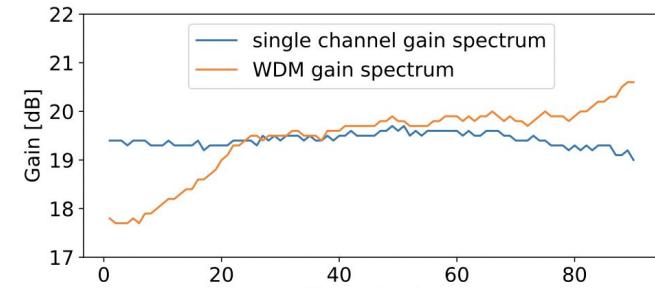
# Wavelength Division Multiplexing Gain Models

$$\hat{g}(\lambda_i) = \frac{G_{TC}}{G_M} \left[ \frac{\sum_j P_j + N_I + N_C}{\sum_j P_j g_j t_j + g_R N_R + g_I N_I} \right] g(\lambda_i)$$

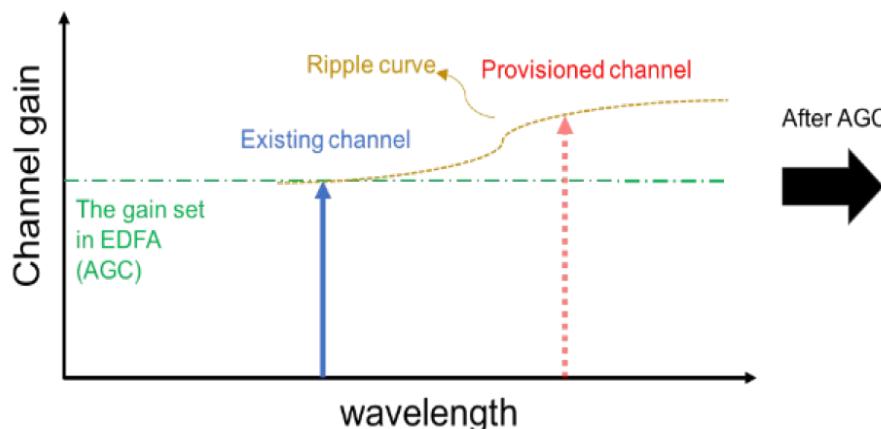
EDFA gain excursion due to a change in channel powers  $P_j$

Equation: J. Junio, et al., JOCN 2012

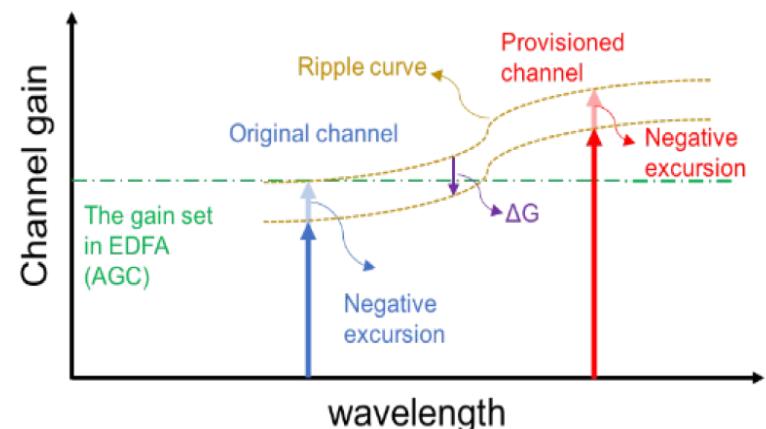
Figures: S. Zhu, et al., OFC 2017



Single channel/WDM gain spectrum



Optical channel power excursion



# Wavelength Division Multiplexing (WDM) Gain Models

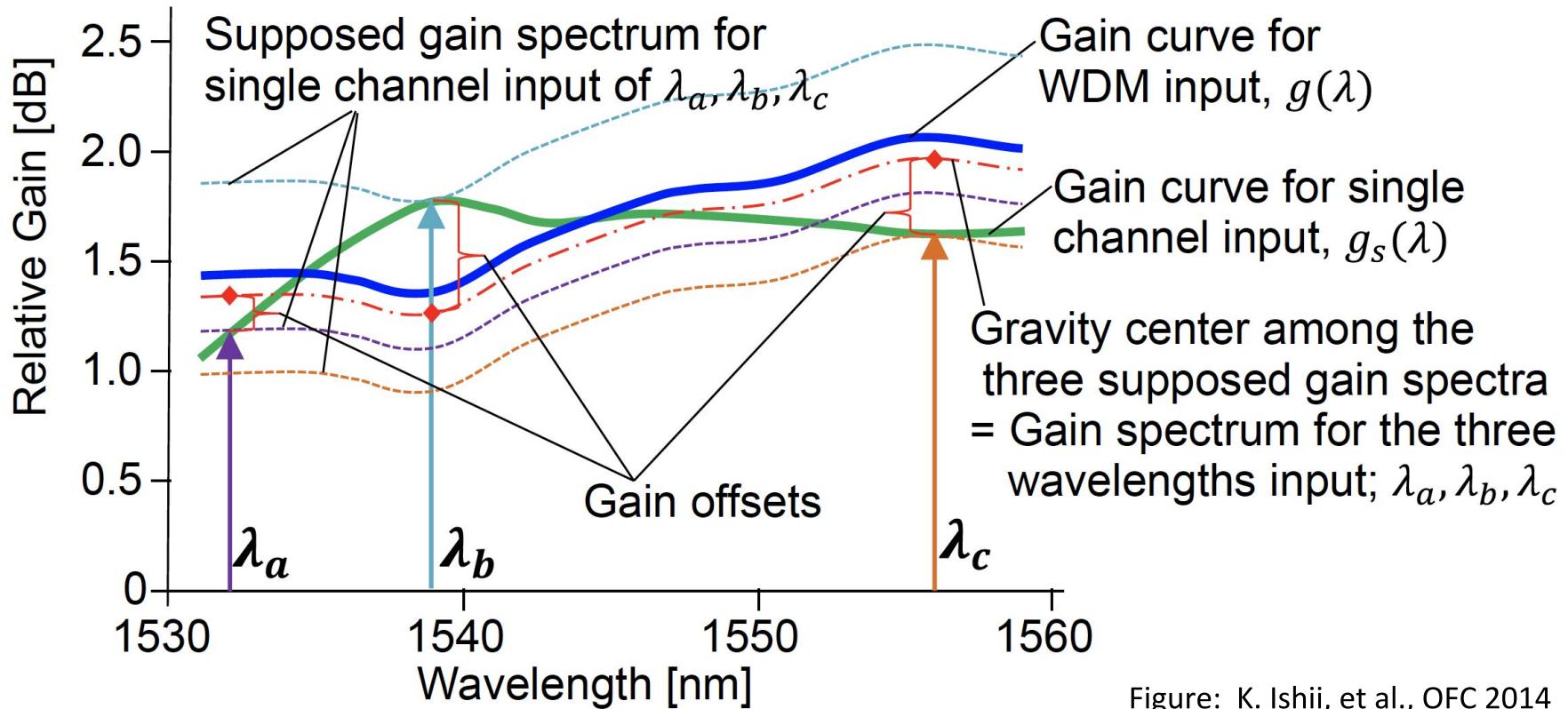
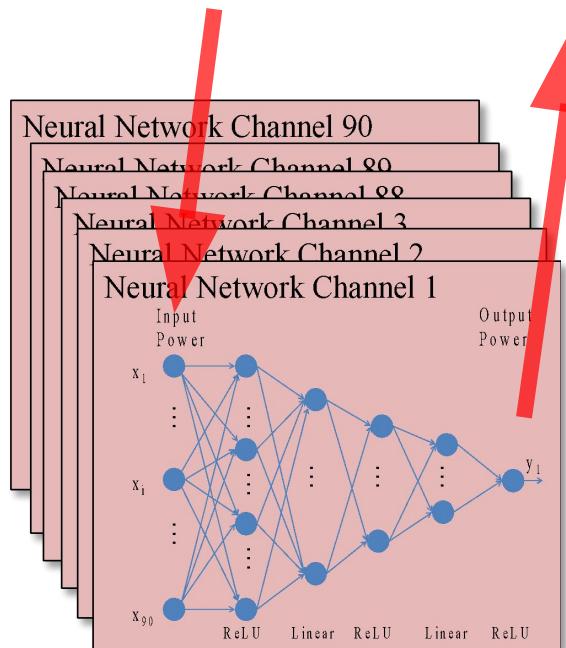
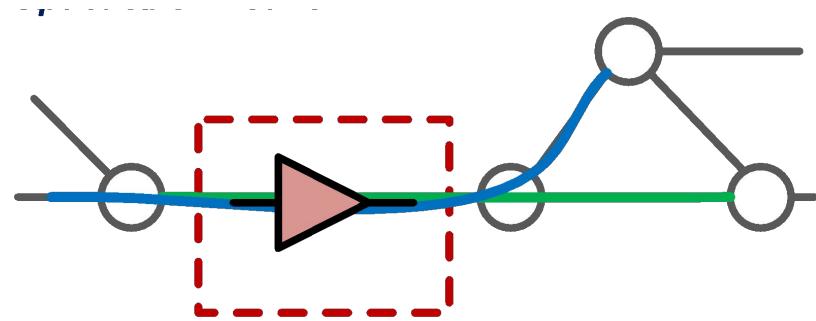
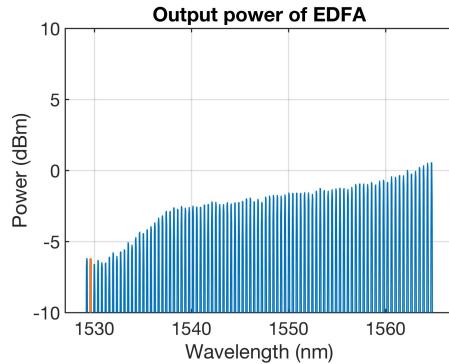
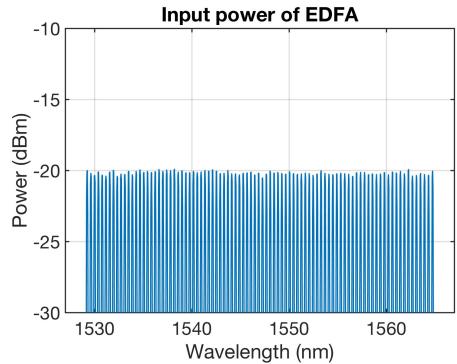


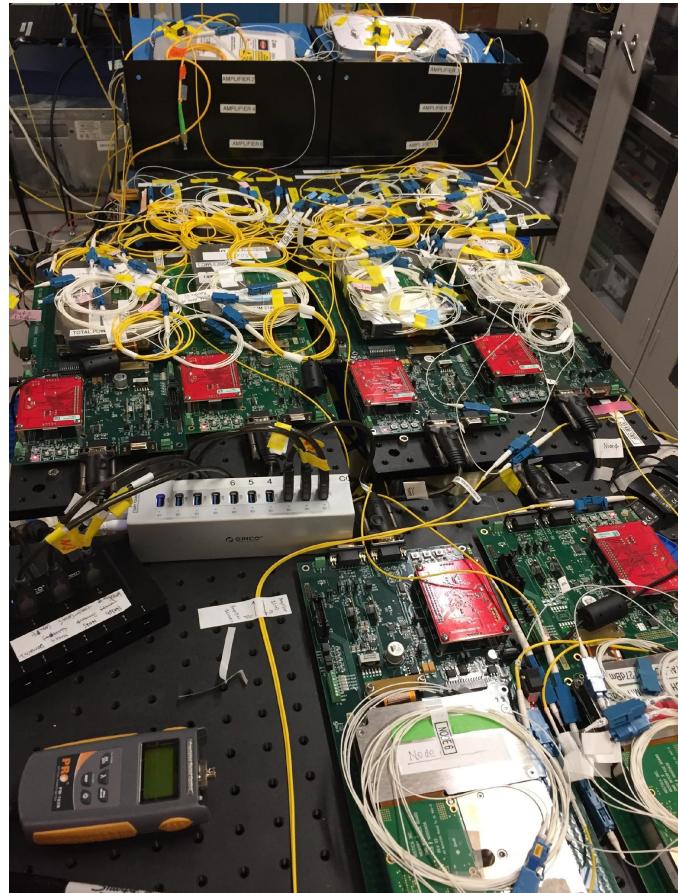
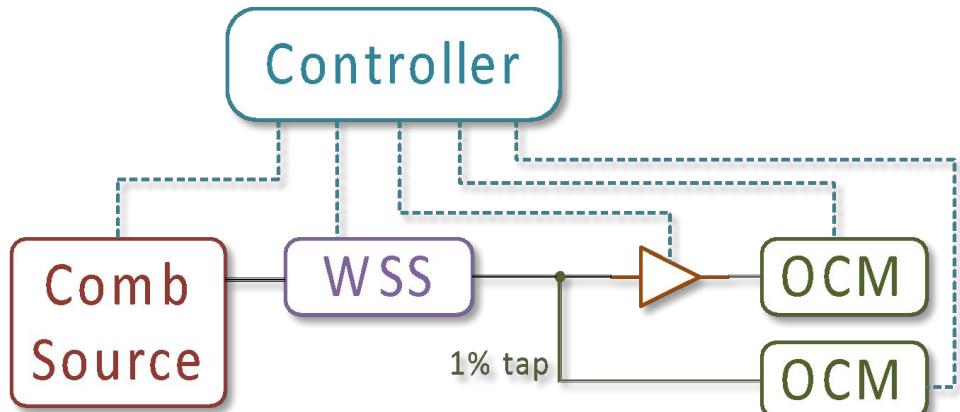
Figure: K. Ishii, et al., OFC 2014



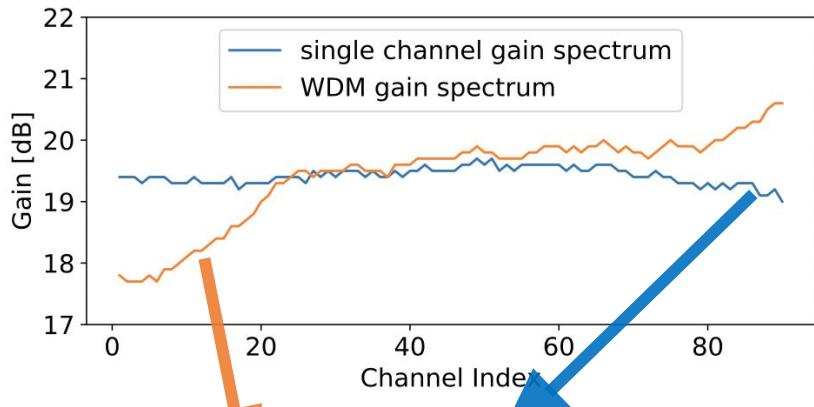
Parameter	Value
Input Vector	$[P_{ch1}, P_{ch2}, P_{ch3}, \dots, P_{ch90}]$
Output Vector	$[P_{ch_i}]$ for $i$ in $[1, 90]$ # $i$ is index of the 90 NNs
Transfer Func.	[ReLU, Linear, ReLU, Linear, ReLU]
Training Target	$\text{Min}\{\text{MSE}\}$
Training Method	Stochastic Gradient Descent (SGD)
Batch Size ( $m$ )	$m = 60$
Learning Rate ( $\alpha$ )	
Training Time	> 15000 iterations

# Experiment Setup

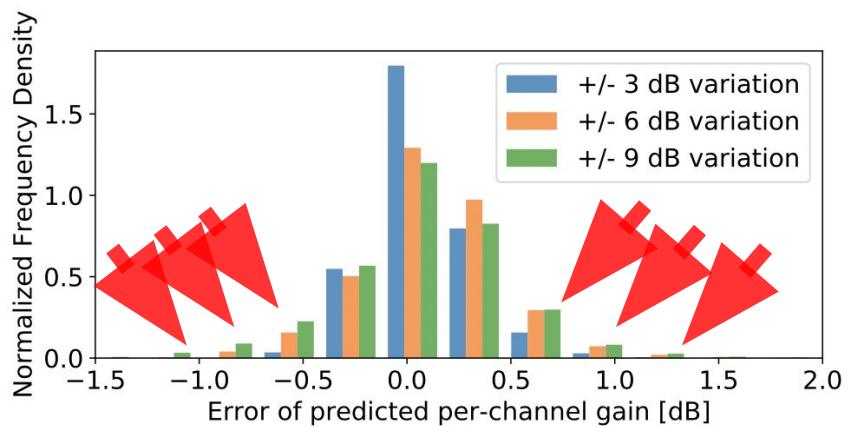
- Validate/test existing models (CM model).
- Capture *true* value of input and output spectrum
- Capture ML *training data, validation data, test data.*



# Test Result (CM model vs. ML model)



$$\hat{g}(\lambda_i) = g(\lambda_i) + \frac{\sum_{j=1}^n [g_s(\lambda_j) - g(\lambda_j)]}{n}$$

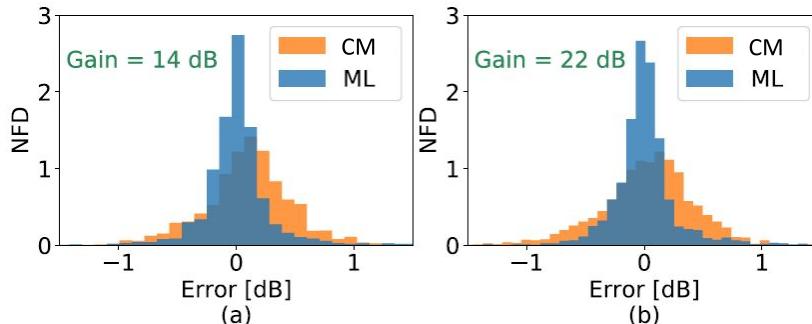


Error distribution of CM model with dynamic range of +/- 3, 6, 9 dB.

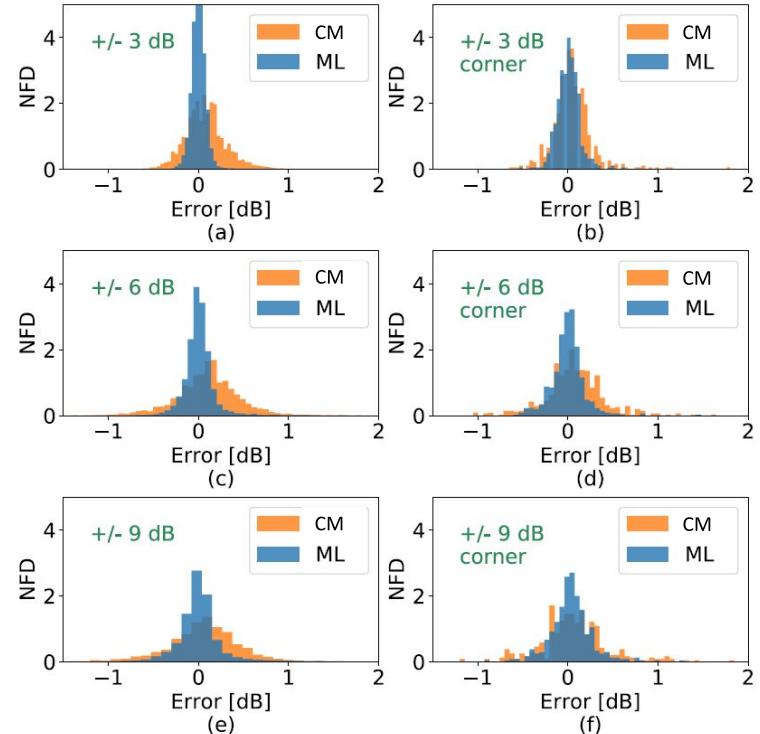
# Test Result (CM model vs. ML model)

Dynamic range [dB]	CM [dB]	ML [dB]
+/- 3	0.247	0.081
+/- 6	0.359	0.180
+/- 9	0.410	0.266

RMSE of analytical model and ML model.



Error distribution of CM model and ML model with gain value of 14 dB and 22 dB.



Error distribution of CM model and ML model with dynamic range of +/- 3, 6, 9 dB.

# Conclusion

1. In this work, a machine learning based modeling method is implemented and studied.
2. Using captured samples of input and output spectrum, Machine learning based model is shown to reduce the gain estimation error compared with analytical model using center of mass method.
3. In the future, this model is to be used to predict QoT in large scale optical networks.

Thank you!  
(Welcome to talk with us later about  
questions and collaborations)

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