Lab Notebook

Pupil Reconstruction

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Contents

1 Amplitude and Phase Reconstruction

16 February 2024

- Create new github branch: `AmpPhaseReconstructionRetraining`
- Download the following the files from Morgana:
  - `superK_slmcube_20230625_complsines-01sp_07`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file00`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file01`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file02`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file03`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file04`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file05`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file06`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file07`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file08`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file09`
- Data processing for Fully Convolutional NN training
- One fast experiment for each file: very good results, around 0.05 validation mse

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- Remove normalization from amplitude and phase for the fully connected experiments

---

EXPERIMENT NewFC10000-Processed 2

HYPERPARAMETERS:

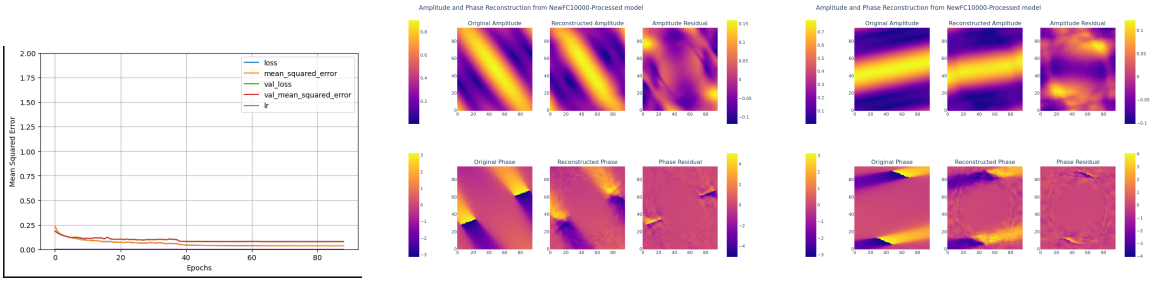
```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 1320
  -Output shape: (2, 96, 96)
  -Hidden layers: [2000, 2000, 2000, 2000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE
```

```
*TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.035130929201841354
      -Validation MSE: 0.0786573588848114
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 1: Results of training the model NewFC10000-Processed 2

EXPERIMENT NewFC30000-Processed-1

HYPERPARAMETERS:

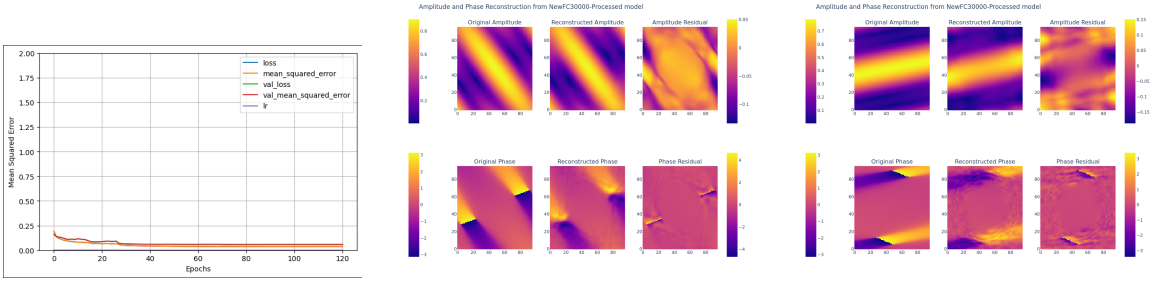
```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 1320
  -Output shape: (2, 96, 96)
  -Hidden layers: [2000, 2000, 2000, 2000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.0357743538916111
      -Validation MSE: 0.057852283120155334
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 2: Results of training the model NewFC30000-Processed-1

EXPERIMENT NewFC80000-Processed-1

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 1320
  -Output shape: (2, 96, 96)
  -Hidden layers: [2000, 2000, 2000, 2000]
  -Regularizer: None
  -Hidden Layers Activation: relu
```

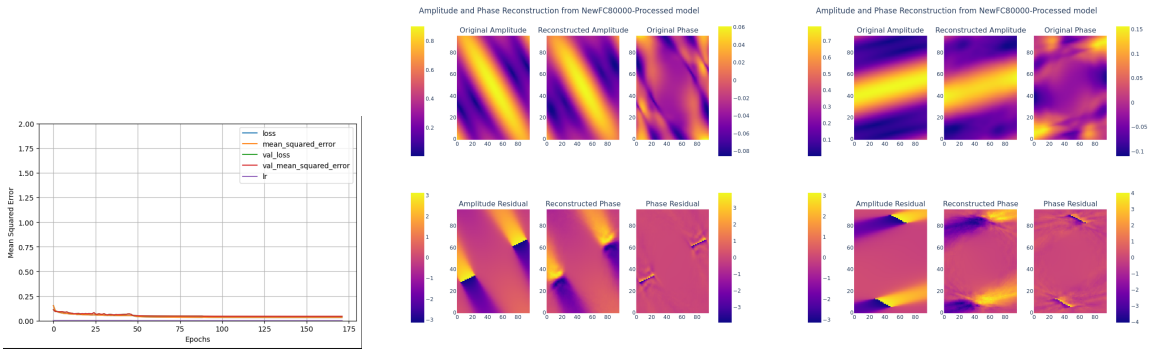
```
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.03301804140210152
      -Validation MSE: 0.04487497732043266
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 3: Results of training the model NewFC80000-Processed-1

- Normalize and split fluxes in train, validation and test files
- Stack amplitude and phase arrays and save in train, validation and test files

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EXPERIMENT NewConv10000-1

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Convolutional
  -Input shape: (55, 24, 1)
  -Output shape: (96, 96, 2)
  -Convolutional Layers: [128, 256, 512]
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3)]
```

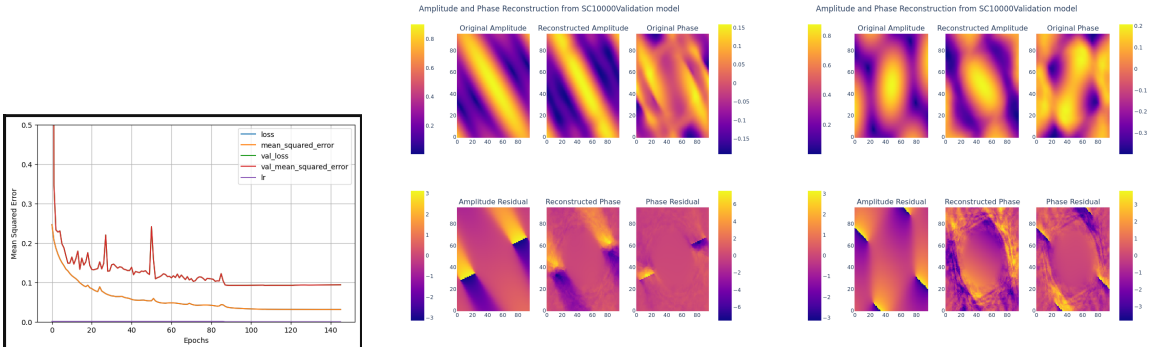
```
  -Fully Connected Hidden layers: [4096, 2048, 2048, 1024, 1024, 102
  -Regularizer: None
  -Convolutional Activation: relu
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: True

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

* TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 15 x0.1
    -Early Stop: MSE 50
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.031087761744856834
      -Validation MSE: 0.09376049041748047
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 4: Results of training the model NewConv10000-1

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EXPERIMENT NewConv30000-1

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Convolutional
  -Input shape: (55, 24, 1)
  -Output shape: (96, 96, 2)
  -Convolutional Layers: [128, 256, 512]
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3)]
```

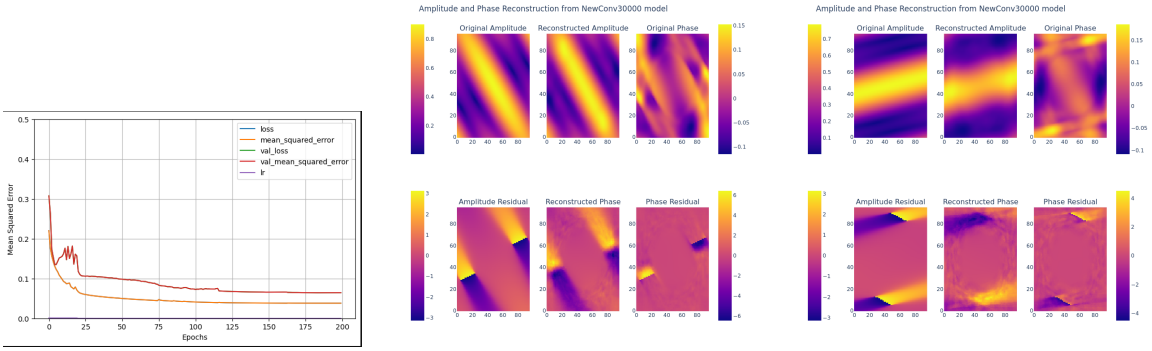
```
  -Fully Connected Hidden layers: [4096, 2048, 2048, 1024, 1024, 102
  -Regularizer: None
  -Convolutional Activation: relu
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: True

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

* TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 15 x0.1
    -Early Stop: MSE 50
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.03819489851593971
      -Validation MSE: 0.06443119794130325
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 5: Results of training the model NewConv30000-1

EXPERIMENT NewConv30000-1

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Convolutional
  -Input shape: (55, 24, 1)
  -Output shape: (96, 96, 2)
  -Convolutional Layers: [128, 256, 512]
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3)]
  -Fully Connected Hidden layers: [4096, 2048, 2048, 1024, 1024, 102
  -Regularizer: None
  -Convolutional Activation: relu
  -Hidden Layers Activation: relu
```

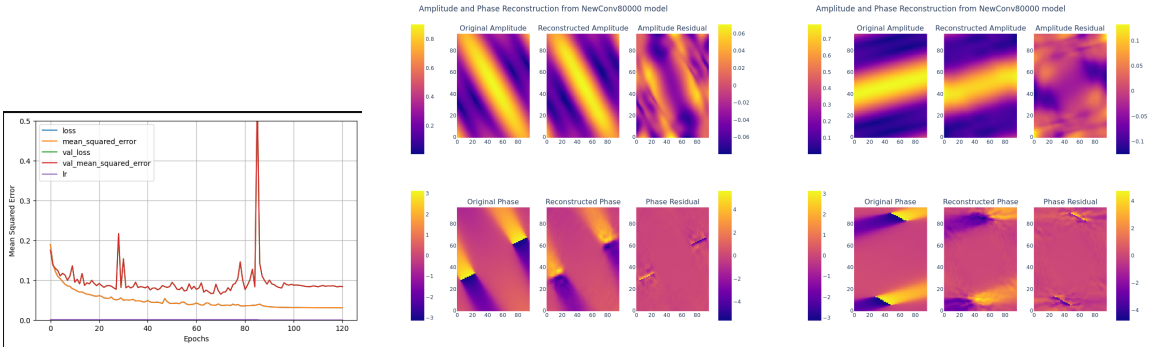
```
  -Output Layer Activation: linear
  -Batch Normalization: True

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

* TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 15 x0.1
    -Early Stop: MSE 50
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.030630357563495636
      -Validation MSE: 0.08355200290679932
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 6: Results of training the model NewConv80000-1

- Normalize flux data and add padding for flux autoencoder
- Stack amplitude and phase and add padding for encoder+convolutional model

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EXPERIMENT NewFluxAutoencoder10000-1

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Autoencoder
  -Input shape: (56, 24, 1)
  -Convolutional Layers: [512, 128, 64, 8]
    (Inverse in the decoder)
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3), (3, 3)]
```

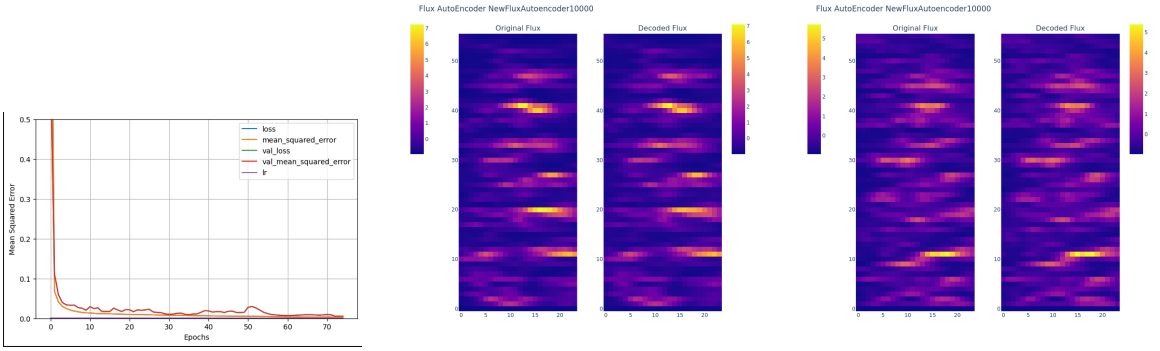
```
    (Inverse in the decoder)
  -Convolutional Activation: relu
  -Output Layer Activation: linear
  -Padding: same
  -Use Batch Normalization: True

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 75
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 8 x0.1
    -Early Stop: MSE 15
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.0018673702143132687
      -Validation MSE: 0.005482238717377186
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 7: Results of training the model NewFluxAutoencoder10000-1

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EXPERIMENT NewFluxAutoencoder80000-1

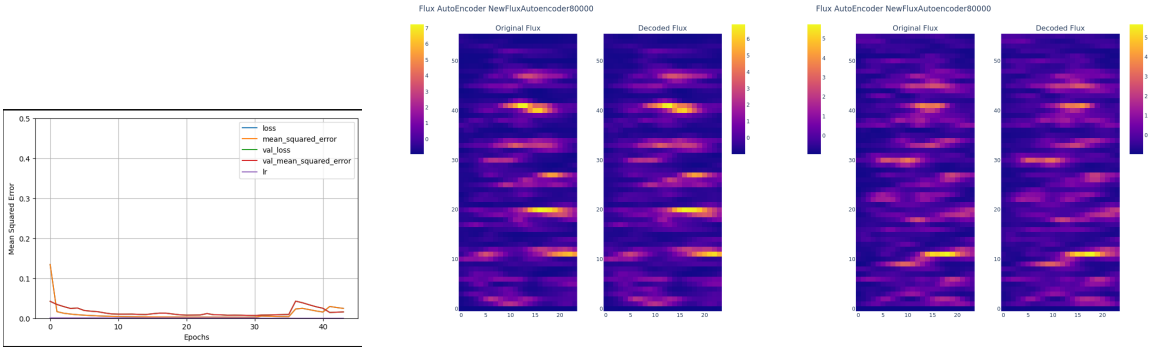
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Autoencoder
  -Input shape: (56, 24, 1)
  -Convolutional Layers: [512, 128, 64, 8]
    (Inverse in the decoder)
```

```
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3), (3, 3)]
    (Inverse in the decoder)
  -Convolutional Activation: relu
  -Output Layer Activation: linear
  -Padding: same
  -Use Batch Normalization: True

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 75
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 8 x0.1
    -Early Stop: MSE 15
```

VISUALIZATION:

```
      -Train MSE: 0.024667566642165184
      -Validation MSE: 0.0158506091684103
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 8: Results of training the model NewFluxAutoencoder10000-1

EXPERIMENT NewEncConv10000-1

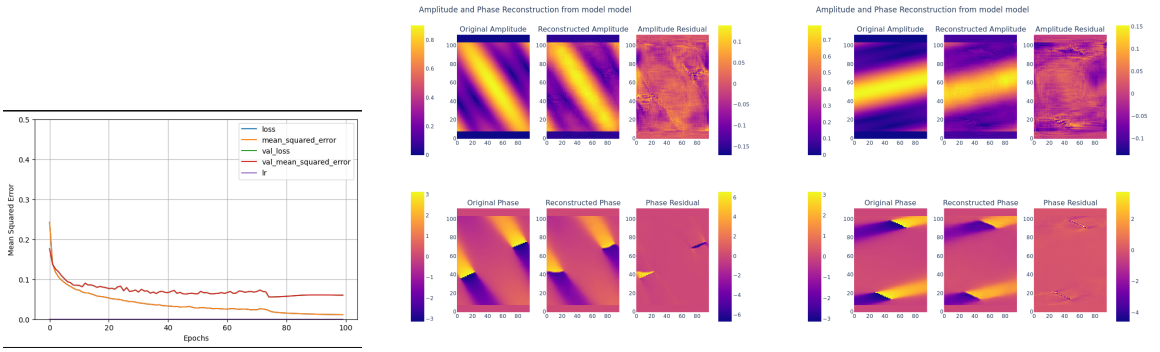
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Encoder + Convolutional
  -Convolutional Layers: [1024, 512, 256, 256]
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3), (3, 3)]
  -Convolutional Activation: relu
  -Output Layer Activation: linear

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.0001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
```

```
   -Metric: MSE


* TRAINING HYPERPARAMETERS:
   -Epochs: 100
   -Batch size: 32
   -Callbacks:
      -ReduceLROnPlateau: MSE 8 x0.1
      -Early Stop: MSE 15
```

VISUALIZATION:

```
*RESULTS:
       -Train MSE: 0.011328332126140594
       -Validation MSE: 0.06024651601910591
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 9: Results of training the model NewEncConv10000-1

EXPERIMENT NewEncConv30000-1

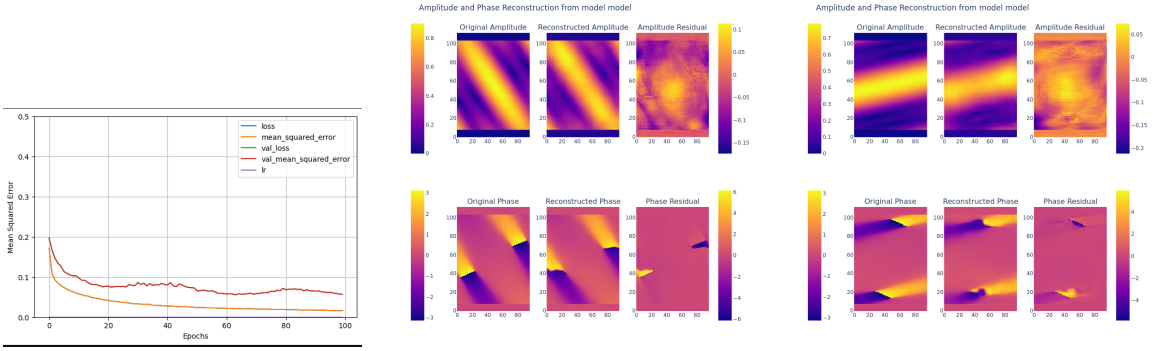
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Encoder + Convolutional
  -Convolutional Layers: [1024, 512, 256, 256]
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3), (3, 3)]
  -Convolutional Activation: relu
  -Output Layer Activation: linear

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.0001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

* TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 8 x0.1
    -Early Stop: MSE 15
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.016221819445490837
```

```
-Validation MSE: 0.05662507936358452
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 10: Results of training the model NewEncConv30000-1

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EXPERIMENT NewEncConv80000-1

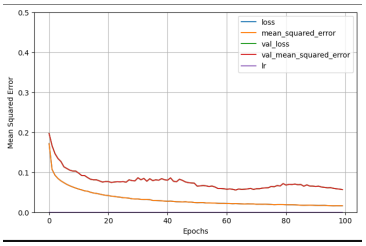
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Encoder + Convolutional
  -Convolutional Layers: [1024, 512, 256, 256]
```

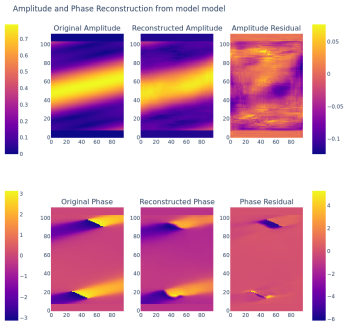
```
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3), (3, 3)]
  -Convolutional Activation: relu
  -Output Layer Activation: linear

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.0001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

* TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 8 x0.1
    -Early Stop: MSE 15
```

VISUALIZATION:

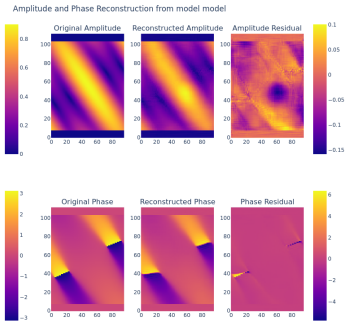
```
*RESULTS:
      -Train MSE: 0.0163
      -Validation MSE: 0.0369
```



(a) IGNORE THIS EVOLUTION FIGURE, TRAINING FINISHED BEFORE STORING THE HISTORY, THIS IS FROM THE PREVIOUS EXPERIMENT



(b) Validation example



(c) Train example

Figure 11: Results of training the model NewEncConv80000-1

2 PSF Reconstruction

20 February 2024

- Create custom dynamic dataloader for PL output flux and PSF complex field for PSF reconstruction

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- Create a dataloader to dynamically load flux and psf
- Normalize electric fields, real and imaginary parts independently
- Normalize PL output fluxes
- Train a fully connected nn with horrible results, train mse keeps stable at 1, will have to look at the data

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- Create plotting functions to show amplitude, phase and intensity from an electric field
- Normalize electric field, this time dividing the complex number matrix by a constant (50.000 in this case)
- Redo output flux calculation with the normalized electric fields through the transfer matrix of the 19 fibre PL

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EXPERIMENT PSF-FC-Reconstructor-1

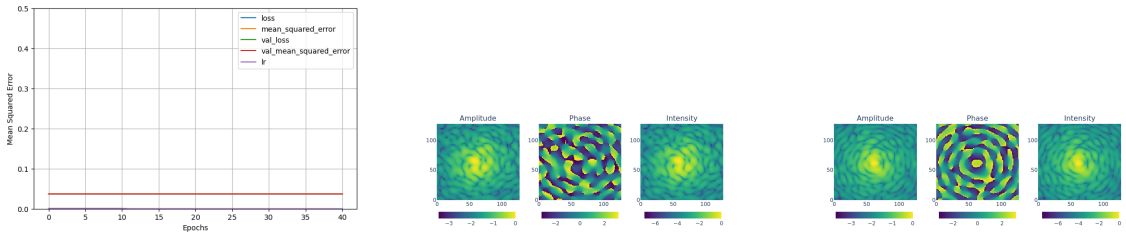
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [2000, 2000, 2000, 2000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 200
```

```
-Batch size: 64
-Callbacks:
  -ReduceLROnPlateau: MSE 10 x0.1
  -Early Stop: MSE 25
```

VISUALIZATION:

```
    -Train MSE: 0.03701553866267204
    -Validation MSE: 0.03701810911297798
```



(a) Training Evolution (b) Validation prediction (c) Validation original

Figure 12: Results of training the model PSF-FC-Reconstructor-1

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- Create a function to plot amplitude and phase predictions and residuals from a complex field