



# Symposium pour l'électronique & le numérique durables

Le 12 décembre 2024, Grenoble

## LSTM surrogate model for SiGe HBT optimization

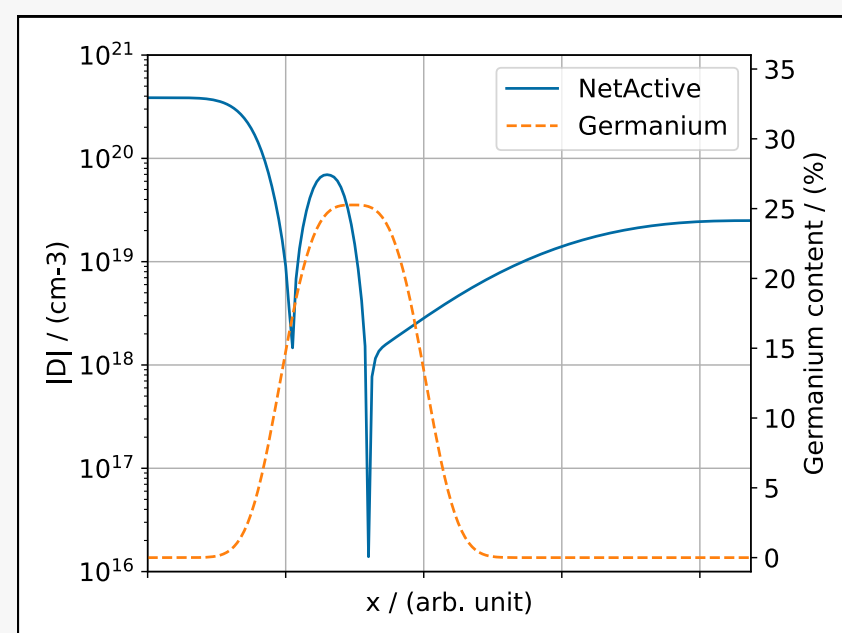
Grégoire Caron<sup>1,2</sup>, Anatoli Iouditski<sup>1</sup>, Nicolas Guitard<sup>2</sup>, Didier Céli<sup>2</sup>

1. Laboratoire Jean Kuntzmann, 700 avenue Centrale, 38400 Saint Martin d'Hères, France  
 2. STMicroelectronics, 850 rue Jean Monnet, 38926 Crolles, France

Heterojunction Bipolar Transistor (**HBT**) design and manufacturing is a process both lengthy and costly in terms of **water, electricity and chemicals**. To converge more rapidly towards an optimized design, one can resort to **TCAD** to simulate HBT electrical characteristics, but it also may require costly **computational resources**.

**Solution:** to train a **Machine Learning (ML)** model [1] to approximate the TCAD simulator, but **much faster**

- I] Build a adapted database
- II] Train a neural net model
- III] Use the model for design



Model

TCAD

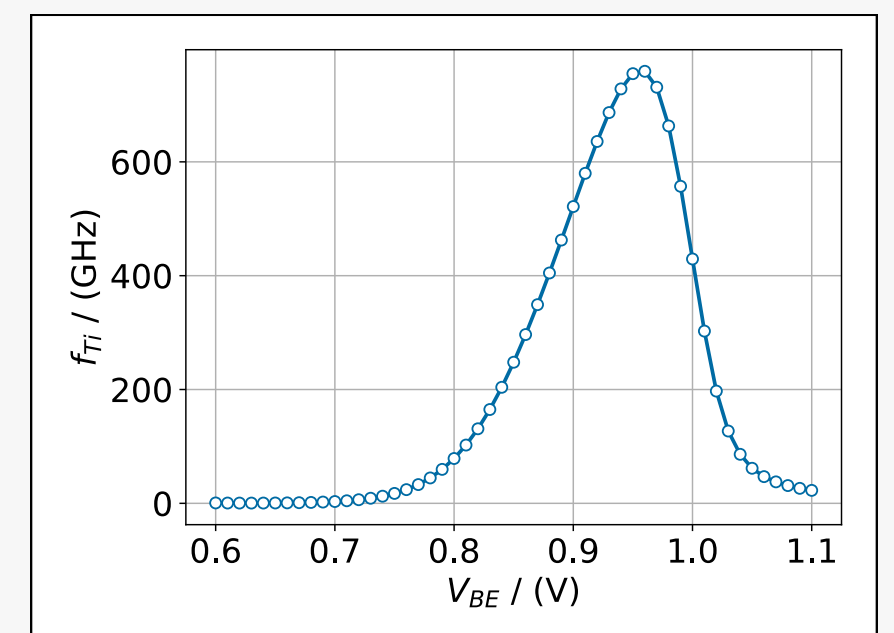


Fig.1: Surrogate modeling

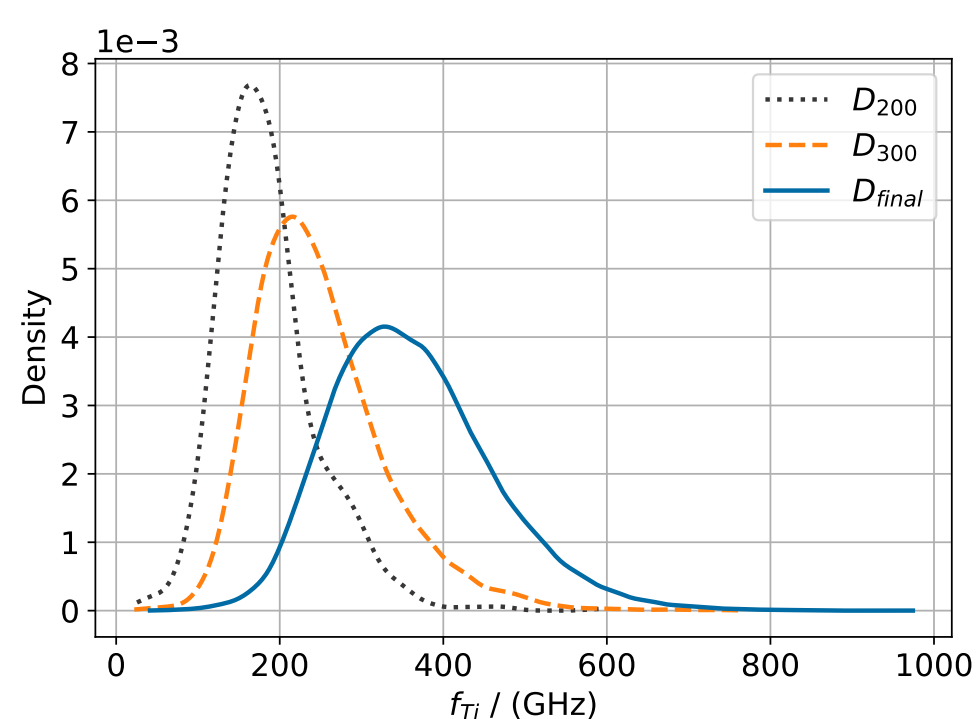


Fig.2: Adaptive importance sampling

### I] Database construction

Contains parameters that describe synthetic HBT doping profiles and the corresponding TCAD-simulated electrical characteristics

**Limit number of simulations** = focus on suitable profiles [2]:

- Realistic: use **Monte Carlo** sampling with rejection, coupled to binary classification method **Support Vector Machine**
- Of technological interest (high transit frequencies  $f_T$ ): use adaptive **importance sampling**

### II] Surrogate model training

Use the database to train Neural Network models  
 Goal: minimize loss (MSE) using gradient descent

Choice of **LSTM decoders** [3] that allow to take into account the regularity of voltage-dependent characteristics  
 Leads to **35% to 60%** gain in prediction accuracy

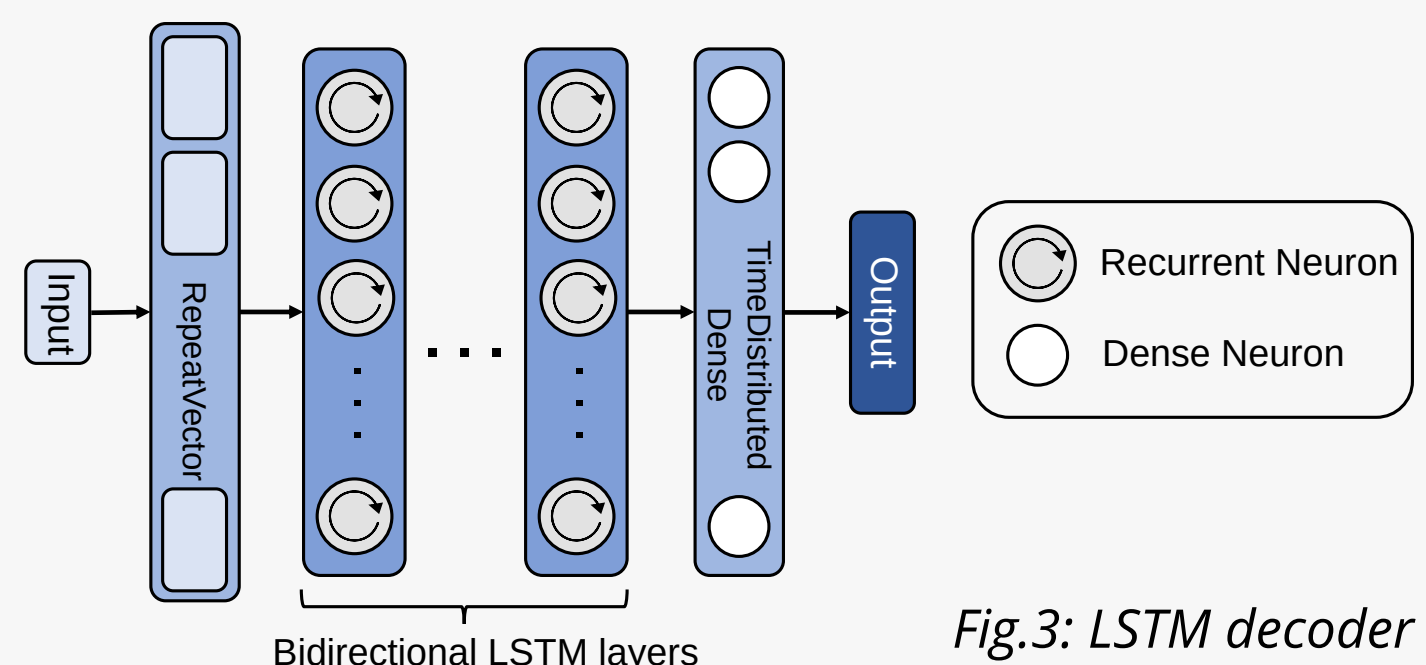
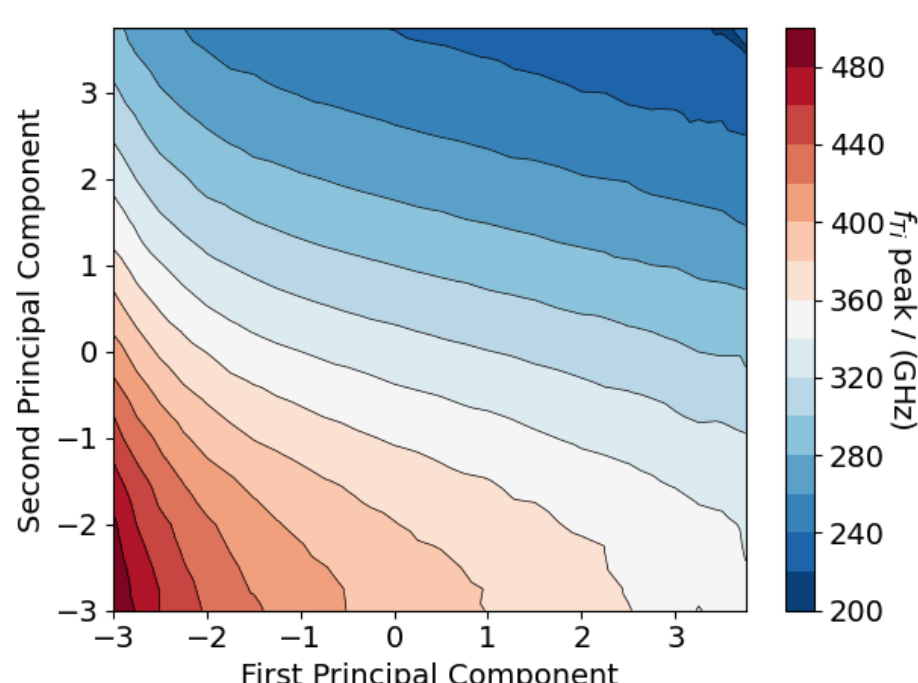


Fig.3: LSTM decoder



### III] Design space exploration

- Generate one million synthetic profiles
- Predict their characteristics very fast, using the surrogate models **instead of months of costly simulations**
- Impose **process restrictions** and **client specifications**
- Retain the best design

Fig.4: PCA of profile parameters with  $f_T$

[1] Jie, X. et al., J Comput Electron 2024  
 [2] Caron, G. et al., IEEE BCICTS 2022  
 [3] Sutskever, I. et al., NeurIPS 2014